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Royal Aeronautical Society

With which is incorporated The Institution of Aeronautical Engineers

A Monthly Illustrated Magazine devoted to all subjects connected with the Navigation of the Air.

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BY

Captain J. LAURENCE PRITCHARD, Hon. Fellow.

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THE ROYAL AERONAUTICAL SOCIETY

(Founded 1866*)*

with which is incorporated the Institution of Aeronautical Engineers

VOLUME XLV

MONTHLY NOTICES,
JANUARY, 1941.

ST. LOUIS PUBLIC LIBRARY
JUL 31 1942

New Year.

The President and Council wish all members a year which will bring peace and goodwill.

Catalogue of the Library.

With this issue of the Journal there begins the printing of the catalogue of the library of the Society, so that it will be available to all members. The catalogue will be published monthly at the end of each Journal until it is completed, and it can then be bound separately. The catalogue will give a complete index, under author and subject, of all books, papers and pamphlets in the library.

1941 New Year Honours.

Knight Bachelor.

F. S. Spriggs, Esq. (Hon. Fellow).

G.C.B. (Civil Division).

R. A. Watson Watt, Esq. (Fellow).

C.B.

Atg. Air Marshal A. G. R. Garrod, O.B.E., M.C., D.F.C. (Associate).
Atg. Air Vice Marshal R. G. Parry, D.S.O. (Associate Fellow).

M.C.

Atg. Sqdn. Ldr. W. W. Straight, A.A.F. (Companion).

C.B.E. (Military Division).

Group Capt. A. de T. Nevill, R.N.Z.A.F. (Associate Fellow).
Group Capt. W. H. Primrose, D.F.C. (Associate).

C.B.E.

S. Camm, Esq. (Fellow).
A. G. Elliott, Esq. (Fellow).
N. Rowbotham, Esq. (Associate Fellow).

O.B.E. (Military Division).

Wing Cmdr. (Temp. Group Capt.) E. C. Wackett, R.A.A.F. (Associate Fellow).
Major E. M. Sinauer (Temp. Lieut.-Col.) M.C. (Associate Fellow).

O.B.E.

Capt. J. G. Hopcraft, M.C. (Associate Fellow).
R. K. Pierson, Esq., M.B.E. (Fellow).
Capt. J. Kelly Rogers, R.A.F.D. (Associate Fellow).

Society's Offices.

It is now permissible to state that in 1940 the Offices of the Society at No. 4, Hamilton Place, suffered a certain amount of damage, due to enemy action. The structure remains sound, but many windows and window frames are blown out. It will not be possible, until the war is over, to give any further details or any indication of the dates on which the bombs fell. A number of the staff were in the building each time, but there were no casualties.

Election of Members.

The following members were recently elected:—

Associate Fellows.—Donald William Loveys Fairbank (from Student), George Steedman Hislop (from Student).

Graduates.—Charles Kenneth Bonner (from Student), Yehuda Giladi (from Student), Ian Malcolm Hamer (from Student), William Frederick George Reynolds (from Student), Kiran Kumar Roy, Henry Ernest Vincent, Leonard Charles Ernest Waspe.

Students.—William Arnold Arnold, James Wesley McGinness, Ralph Todd.

Members' Subscriptions.

Members are reminded that their subscriptions were due on January 1st, 1941. The Council hope that every member will make an effort to pay his subscription as early as possible to save postage on reminders. The rates are:—

	Home. £ s. d.	Abroad. £ s. d.
Founder Member	2 2 0	2 2 0
Fellow	4 4 0	3 3 0
Associate Fellow	3 3 0	2 2 0
Associate	*2 2 0	*2 2 0
Graduate	2 2 0 (21-26 years)	
	2 12 6 (26-28 years)	
Student	1 1 0	1 1 0
Companion	2 2 0	2 2 0

* Without Journal.

Back Numbers of the Journal.

Owing to the limited number of Journals printed during the war period there is a scarcity of certain issues of 1940. The Secretary would be very grateful to receive back any copies Members have finished with, in particular the January, 1940, issue.

Society's Emergency Address.

It should be made clear that although the Society has published from time to time in the Journal its emergency address and telephone number (which can be used at any time alternatively with those of the Society), the Society functions, and has functioned from the beginning of the war, from No. 4, Hamilton Place, W.1. It will continue to function from London as far as possible, even though some of the staff may have to be moved, others will continue in London itself. It is obvious that events may make things difficult and cause a certain amount of delay, and members are asked to bear these events in mind.

The emergency address is—

Brook House,
Old School Lane,
Brockham, Surrey.

Telephone: Betchworth 189.

Coventry Branch Scholarship.

The Coventry Branch Scholarship has been awarded this year to Mr. Kenneth William Norris, 26, Seneschal Road, Coventry. The scholarship is tenable for two years.

These scholarships are awarded with the object of encouraging and assisting branch members to become Associate Fellows. Candidates must be members of the branch and must sit for the Associate Fellowship Examination and for the Higher National Certificate.

Additions to the Library.

Sec. Ref.

E.b.80.—Graphical Treatment of Vibration and Aircraft Engine Dampers. By C. H. Powell. Bookcraft (New York). 1940. $7.50.

E.f.70.—Aero Engines (Inspection of, during Manufacture, Overhaul and Test). ("D" Licence.) By A. N. Barrett. Sir Isaac Pitman. (7th Edition.) 1940. 3/6.

*G.b.3 and 4.—British Standards Institution, Specifications. (Price 1/- each.) 1940:—

5F.16.—Rubber Shock Absorber Cord.

3F.51.—Light Elastic Cord for Parachutes, W/T Instruments and Aerial Suspensions.

2T.52.—Hard-Drawn Phosphor-Bronze and Phosphorus Deoxidised Bronze Tubes.

*G.b.31.—Bakelite Laminated Materials: Technical Information. (Loose-leaf data book.) Published by Bakelite, Ltd.

I.a.13.—Teach Yourself Trigonometry. By P. Abbott. English Universities Press. 1940. 2/6.

I.a.14-17.—Series: University Mathematical Texts. Published by Oliver and Boyd. 4/6 each:—

Theory of Equations. By H. W. Turnbull. 1939.

Vector Methods. By D. E. Rutherford. 1939.

Statistical Mathematics. By A. C. Aitken. 1939.

Determinants and Matrices. By A. C. Aitken. 1939.

I.a.18.—Advanced Algebra. By S. Barnard and J. M. Child. Macmillan and Co. 1939. 16/-.

I.b.15-17.—Series: University Mathematical Texts. Published by Oliver and Boyd. 4/6 each:—

Integration of Ordinary Differential Equations. By E. L. Ince. 1939.

Integration. By R. P. Gillespie. 1939.

Functions of a Complex Variable, with Applications. By E. G. Phillips. 1940.

Q.b.60.—Records and Research in Engineering and Industrial Science. By J. Edwin Holmstrom. Chapman and Hall. 1940. 15/-.

R.f.60.—Some Milestones in Aviation. By Capt. W. E. Johns. (Undated, about 1935.) John Hamilton, Ltd. 6/-.

R.f.61.—Deeds that Held the Empire. By Air-Commodore L. E. O. Charlton. John Murray. 1940. 7/6.

S.a.77.—An Airman Remembers. By Hans Schröder. John Hamilton. (Undated, about 1936.) 10/6.

S.a.118.—Flight into Hell: the Story of the Lafayette Escadrille. By Edwin C. Parsons. John Long. 1938. 8/6.

T.b.65.—Pacific Flight: the Story of the "Lady Southern Cross." By P. G. Taylor. John Hamilton. (Undated, about 1936.) 8/6.

T.b.66.—Thrilling Flights. Various Authors. (Ed. by Capt. W. E. Johns.) John Hamilton. (Undated, about 1935.) 3/6.

T.b.67.—That's My Story. By Douglas Corrigan. Robert Hale. 1939. 7/6.

T.b.68.—A Passport Round the World. By Charles H. Holmes. Hutchinson and Co. 1937. 12/6.

UL.5.—Japanese Journal of Engineering: Abstracts. (Papers published in 1939.) National Research Council of Japan. 1940.

UL.6.—Aeronautical Research Institute, Tokyo Imperial University. Reports (1940):—

No. 191. Measurement of the Period of Natural Vibration of an Airscrew Blade. By J. Obata.

No. 192. Viscosity Characteristics of Lubricating Oils as Related to Their Chemical Structure. (In Japanese, with English Summary.)

No. 193. Dynamical Stability of a Column Under Periodic Longitudinal Forces. By I. Utida and K. Sezawa.

No. 194. On the Subsonic Flow of a Compressible Fluid Past an Elliptic Cylinder. By I. Imai and T. Aihara.

No. 195. Some Experiments on the Forced Vibration of Varying Period. By K. Sezawa and W. Watanabe.

*V.5.—Institution of Mechanical Engineers: Proceedings. Vol. 143. (Jan.-June, 1940.)

*V.7.—Institution of Naval Architects. Transactions. Vol. LXXXII. 1940.

* Books marked thus may not be taken out on loan.

J. LAURENCE PRITCHARD, *Secretary and Editor.*

SOME THEORETICAL CONSIDERATIONS ON BOX BEAMS.

By Jean Drymael,

Assistant Professor in the University of Brussels.

Summary.

Box beams, built up essentially with flanges and webs are widely used in aircraft construction and much has been written about their calculation. But often assumptions are implicitly made without reason. The first aim of this paper is to point out which assumptions must be chosen and why, and to show what results may be expected from them. The calculations are then developed in the cases of the quadrangular box beam and the wing with three spars (redundancy of the first degree).

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Single Spar with Curved Web.

1. Definition. 2. Stress of the flanges. 3. Stress of the web. 4. Strain of the flanges. 5. Strain of the web. 6. Remarks.

Geometrical Properties of the Cross Section of a Box Beam.

7. Separation of the work of flanges and webs. 8. Properties of the set of flanges. 9. Properties of the set of webs. 10. Rotation of the axes. 11. Translation of the axes.

Statically Determinate Beams.

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Statically Indeterminate Beams.

16. Redundancy. 17. Webs infinitely rigid. 18. Flanges infinitely rigid. 19. Bulkheads. 20. Redundancy of the first degree.

Quadrangular Box Beam.

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Wing with Three Spars.

28. Stress of the webs. 29. Stress of the flanges. 30. Equation of U. 31. Limit conditions.

Conclusion.

Single Spar with Curved Web.

1. Definition.

Let it be supposed that the spar, prismatic, consists of two flanges bound together by a cylindrical shell (Fig. 1).

It is assumed that the transverse dimensions of the flanges are small compared with those of the beam, and the cross section of the web is small compared with that of the flanges. The centre of gravity G of the cross section coincides thus with the centre of gravity of the flanges. Let the longitudinal axis X pass

through this point and the Z axis be the axis joining the flanges in a particular cross section. The Y axis forms with them a left-hand system.

2. Stress of the Flanges.

It is assumed, following the theory of Barré de St. Venant, that there is no transverse stress between the longitudinal fibres of the beam, *i.e.* :—

$$\sigma_Y = \sigma_Z = \tau_{YZ} = 0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It follows from this assumption and from the indefinite equations of equilibrium that the shear stresses τ_{XY} and τ_{ZX} must be independent from X, and that the longitudinal normal stress σ_X must be a linear function of the same co-ordinate. It is thus implied that the shears are constant along the whole length of the beam.

The indefinite equations of compatibility show that σ_X is a linear function of the transverse co-ordinates Y and Z. Since the product of inertia of the cross section about the Y and Z axes is zero, and the moment of inertia about the Z axis is negligible, the bending moment must act in the ZX plane and σ_X is independent from Y; in each section

$$\sigma_X = \sigma_G + Z\frac{\partial \sigma_X}{\partial Z} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

σ_G being the value of σ_X on the X axis.

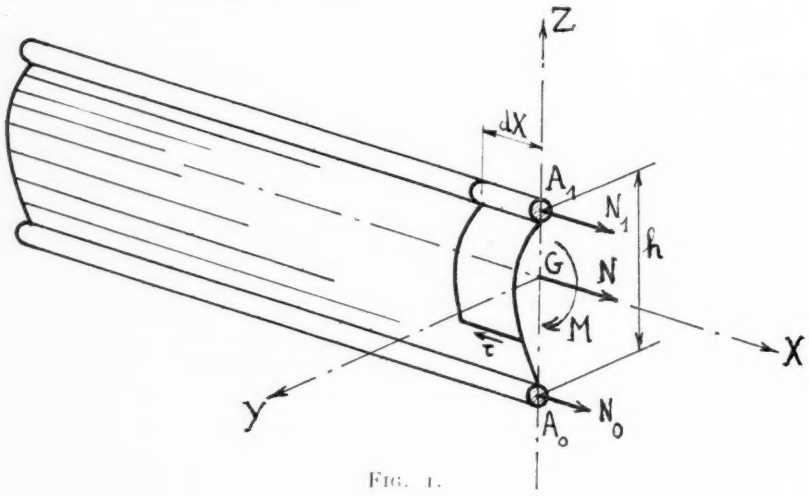

Fig. 1.

The total normal force and the bending moment on the beam equal

$$N = \int_A \sigma_X \, . \, dA = \sigma_G \, . \, A \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$M = \int_A \sigma_X \, . \, Z dA = \frac{\partial \sigma_X}{\partial Z} \, I \quad . \quad . \quad . \quad . \quad . \quad (4)$$

A and I being the total area and the moment of inertia of the section; by definition the part played in them by the web is negligible. It follows that the normal force in either flange equals :—

$$N_i = A_i \, . \, \sigma_i = \frac{A_i}{A} N + \frac{A_i Z_i}{I} M \qquad (i = 0, \; 1) \, . \quad . \quad . \quad (5)$$

and is independent of the size and shape of the web.

It will be supposed that the total normal force N acting on the beam is constant along the length. The derivative of the force in either flange equals thus :—

$$\frac{dN_1}{dX} = \frac{A_1 Z_1}{I} \frac{dM}{dX} = \frac{A_1 Z_1}{I} S \qquad (6)$$

S being the shear.

3. Stress of the Web.

The shear stress on both faces of the web being zero, the shear stress τ on the cross section of the web is necessarily parallel to the mean line of the web (Fig. 2).

Let the element of beam be considered which is limited by two infinitely near cross sections and located above the level Z (Fig. 1). Its equilibrium in the X direction is expressed by

$$\tau t = \int_z^{z_1} \frac{\partial \sigma_x}{\partial X} dA = \frac{S}{I} u_z^{Z_1}$$

t being the thickness.

$u_z^{Z_1}$ being the static moment about Y of the part of cross section located above the level Z.

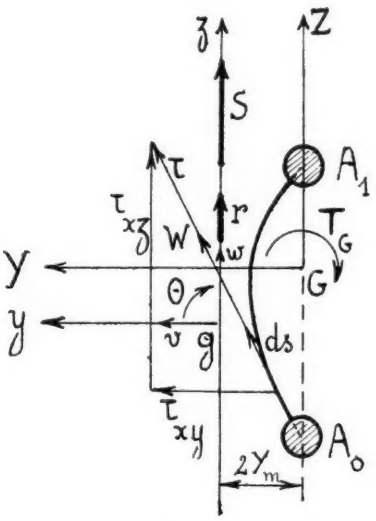

Fig. 2.

Since the area of the web is negligible against the area of the flange, this moment is constant and equals

$$u = A_1 Z_1$$

The moment of inertia being

$$I = A_0 Z_0^2 + A_1 Z_1^2 = A_1 Z_1 h$$

the product of the shear stress by the thickness equals

$$\tau t = \frac{S}{h} \qquad (7)$$

It is constant along the whole height of the section. If, as usual, the thickness is constant, the shear stress is constant and equals

$$\tau = \frac{S}{ht} \qquad (8)$$

The shear stress in the web is thus independent of the size and shape of the flanges; it depends only on the height and thickness of the web and not on its shape.

The projections of the shear stress on the Z and Y axes equal

$$\tau_{ZX} = \tau \frac{dZ}{ds} \qquad \tau_{XY} = \tau \frac{dY}{ds} \qquad (9)$$

ds being the element of arc along the mean line of the web.

The twisting moment about G equals

$$T_G = \tau t \int_0^1 (Y dZ - Z dY) \qquad (10)$$

The integral equals twice the area limited by the web and the Z axis, that is $2hY_m$, if Y_m is the mean distance between the web and the axis. Hence

$$T_G = 2\, th\tau Y_m = 2\, SY_m \qquad (11)$$

The resultant shear is applied excentrically at a distance $2Y_m$ from the Z axis. The straight line along which it acts is called the axis z of the web.

4. Strain of the Flanges.

Let u, v, w, be the displacements of any point of the beam along the axes. The extension of either flange is

$$\varepsilon_i = \frac{du_i}{dX} = \frac{1}{E}\left[\frac{N}{A} + \frac{Z_i M}{I}\right] \qquad (12)$$

The slope of the cross section, considered as positive when the section turns in the ZX direction, is, since the displacements are small: $(u_1 - u_0)/h$.

Hence the curvature, considered as positive when the concavity is turned downwards equals

$$\frac{1}{h}\left(\frac{du_1}{dX} - \frac{du_0}{dX}\right) = \frac{M}{EI} \qquad (13)$$

In the solid beams this well-known expression is generally adopted as the curvature of the elastic axis of the beam. As long as no concentrated loads are applied on the beam this may still be considered as true; the integration does not give the slope of the elastic line but that of the cross section, which may be quite different.

5. Strain of the Web.

Since the transverse stress between the longitudinal fibres of the beam is zero (Eq. 1), the deformation of the cross section is due only to the Poisson's contractions, and is thus small. The displacement of the cross section in its own plane consists chiefly of a movement as a whole. Let the point g, on the z axis, be chosen as reference and r be the displacement of this point, in the Z direction. Let r_g and θ be the translation in the Y direction and the rotation about g (Fig. 2). The projections of the displacement W of any point of the cross section are

$$v = r_g - z\theta, \qquad w = r + (Y - 2\, Y_m)\,\theta.$$

The distortion of an element of web in its own plane is

$$\gamma = \frac{\partial u}{\partial s} + \frac{\partial W}{\partial X} = \frac{\tau}{G} \qquad (14)$$

It is constant along the whole height. Thus, if both members are multiplied by ds and integrated

$$u_1 - u_0 + \frac{\partial}{\partial X}\int_0^1 W \,.\, ds = \frac{\tau s}{G}$$

s being the length of the mean line of the web.

The product under the integral equals

$$W \,.\, ds = v\,dY + w\,dz.$$

Thus

$$\int_0^1 W \,.\, ds = \theta \int_0^1 (Y\,dz - z\,dY) + rh - 2\,\theta Y_m h.$$

The first and last terms cancel each other so that

$$\frac{\tau \,.\, s}{G} = \frac{S \,.\, s}{htG} = u_1 - u_0 + h\,\frac{dr}{dX}$$

If the expression

$$a = st \,.\, \frac{h^2}{s^2} = \frac{th^2}{s} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

is called the reduced area of the web* the shear becomes

$$S = Ga\left[\frac{u_1 - u_0}{h} + \frac{dr}{dX}\right] . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

The first term in the brackets is the slope of the cross section, previously determined by the study of the flanges, and the second term is the relative sliding of the cross sections along the z axis, or slope of the elastic axis.

To summarise, the single spar with curved web is able to withstand, thanks to the flanges, a normal force N and a bending moment M, and thanks to its web, a vertical shear S applied on the axis of the web.

The deformation consists of

—an extension due to the normal force.
—a curvature due to the bending moment.
—a distortion in the " plane " of the web.

All the other deformations, *i.e.* :—

—the curvature and distortion in the horizontal plane, and
—the twisting,

are indeterminate.

6. Remarks.

Transverse Stresses.—Even if there is a distributed load on the beam the transverse stresses between the longitudinal fibres are necessarily small compared with the longitudinal stresses, which are as near as possible to the yielding stresses.

Taper.—If the beam is slightly tapered instead of being prismatic, the error made is small, and places the designer on the safe side, as regards the web, when, as usual, the dimensions of the section grow in the same direction as the bending moment.

Stiffeners.—Since the stresses are distributed over the cross section in a well defined way, wherever an external load is applied, a means must be provided which distributes that load in the correct way. Thus, even a single spar cannot be used without stiffeners. They may be very light since they bear only the local loads.†

* For a plane web the reduced area equals the true area.

† Except if the web buckles, but this kind of failure is not considered here.

Concentrated Loads.—If concentrated loads are applied on the beam they should be conveniently distributed along a sufficient length lest a local failure should happen.

Geometrical Properties of the Cross Section of a Box Beam.

7. Separation of the Work of Flanges and Webs.

Generalising the previous conclusions, it will be assumed that in any box beam each flange bears only a normal force and each web only a shear.

Thus, if the external load takes any form, the set of flanges must withstand in each cross section—

—the normal force;
—the bending moments;

and the set of webs must withstand

—the total shears;
—the twisting moment.

They work independently of each other and their geometrical properties must be studied separately.

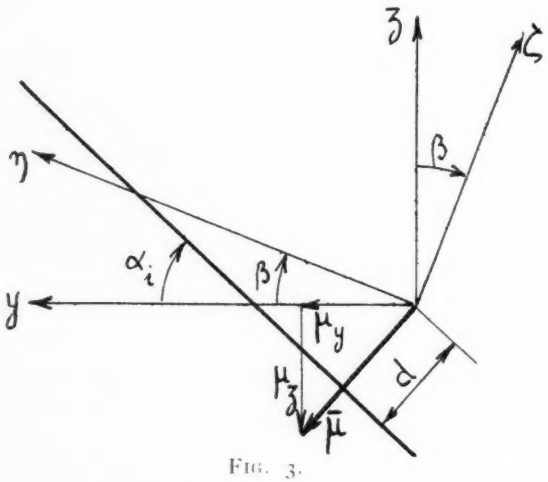

Fig. 3.

8. Properties of the Set of Flanges.

Each flange may be considered as a point of given area. This set of points is defined as regards two axes YZ by

—one total area;
—two static moments;
—three moments of second order.

It need hardly be recorded that the static moments are zero when the origin coincides with the centre of gravity, and that the product of inertia, or cross moment of second order is zero when the axes coincide with the principal axes of the set.

9. Properties of the Set of Webs.

Each web is defined by an axis and a reduced area. Let this area be "directed" along the axis. Let the i web (Fig. 3) make the angle α_i with the

y axis. As regards the axes yz, three areas will be defined for that particular web:—

$$\left.\begin{array}{l}\text{—the area along the } y \text{ axis: } a_y = a_i \cos^2 \alpha_i \\ \text{—the area along the } z \text{ axis: } a_z = a_i \sin^2 \alpha_i \\ \text{—the cross area: } \qquad a_{yz} = a_i \sin \alpha_i \cos \alpha_i\end{array}\right\} \quad . \quad . \quad (17)$$

If the web is parallel to an axis the area along that axis equals the reduced area of the web, and the other areas are zero.

The static moment of the web about the origin is a vector μ, perpendicular to the web and directed from the origin towards it, the length of which equals the product of the reduced area by the distance d (Fig. 3). The projections of this vector on the axes are called the static moments about the axes, they are

$$\mu_y = a_i d_i \sin \alpha_i \qquad \mu_z = -a_i d_i \cos \alpha_i \quad . \quad . \quad . \quad . \quad (18)$$

The moment of inertia of the web about the origin is, by definition, the product of the reduced area by the square of the distance

$$i = a_i d_i^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

By adding together the expressions corresponding to the various webs one defines a set of webs by

—three total areas.
—two static moments.
—one moment of inertia.

10. Rotation of the Axes.

If a new set of axes $\eta\zeta$ is chosen which makes the angle β with the old one (Fig. 3), the direction of each web is changed by the same amount. Thus the total areas become

$$\left.\begin{array}{l} a_\eta = \Sigma\, a_i \cos^2 (\alpha_i - \beta) \\ a_\zeta = \Sigma\, a_i \sin^2 (\alpha_i - \beta) \\ a_{\eta\zeta} = \Sigma\, a_i \sin (\alpha_i - \beta) \cos (\alpha_i - \beta) \\ \qquad = \tfrac{1}{2} \left[\cos 2\beta \, \Sigma\, a_i \sin 2\alpha_i - \sin 2\beta \, \Sigma\, a_i \cos 2\alpha_i\right] \end{array}\right\} \quad . \quad . \quad (20)$$

If β takes one of the values defined by

$$tg\, 2\beta = \frac{\Sigma\, a_i \sin 2\alpha_i}{\Sigma\, a_i \cos 2\alpha_i} \quad . \quad . \quad . \quad (21)$$

the cross area of the set is zero. The directions so defined, forming only one pair of orthogonal lines, are the principal directions of the set at the considered point.

If the areas along the axes issued from the origin are represented by vectors on the respective directions, their ends describe an ellipse, and the principal directions of the set of webs are the axes of the ellipse.

11. Translation of the Axes.

Static Moments.—If a new set of axes is chosen, parallel to y and z (Fig. 4), the new co-ordinates equal:—

$$\eta = y - y_o, \quad \zeta = z - z_o.$$

The total areas of the set of webs do not change, and the principal directions remain the same. The static moments become:—

$$\left.\begin{array}{l} \mu_\eta = \Sigma\, a_i \delta_i \sin \alpha_i = \mu_y + z_o a_{yz} - y_o a_z \\ \mu_\zeta = -\Sigma\, a_i \delta_i \cos \alpha_i = \mu_z - z_o a_y + y_o a_{yz} \end{array}\right\} \quad . \quad . \quad . \quad (22)$$

If the axes y and z are parallel to the principal directions of the set, it is seen that the static moment in O equals the static moment in A, plus the moments about O of the axes y and z bearing respectively the areas a_y and a_z.

Centre of Gravity.—There is thus one point about which the static moment of the set is zero. That point is called centre of gravity g. If the axes are

parallel to the principal directions its co-ordinates are

$$y_0 = \frac{\mu_y}{a_z}, \qquad z_0 = \frac{\mu_z}{a_y} \qquad (23)$$

The principal directions issued from the centre of gravity are the *principal axes* of the set of webs. Henceforth it will be supposed that the axes y and z are those axes. If they are granted the areas a_y and a_z they are equivalent to the set as regards the areas and the static moments.

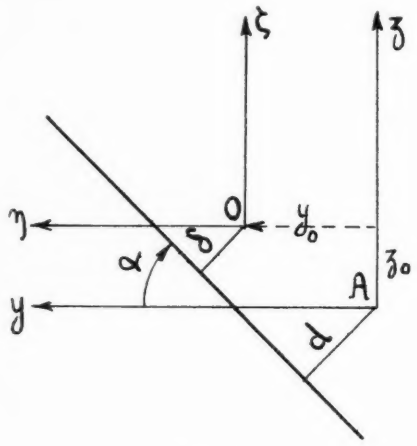

FIG. 4.

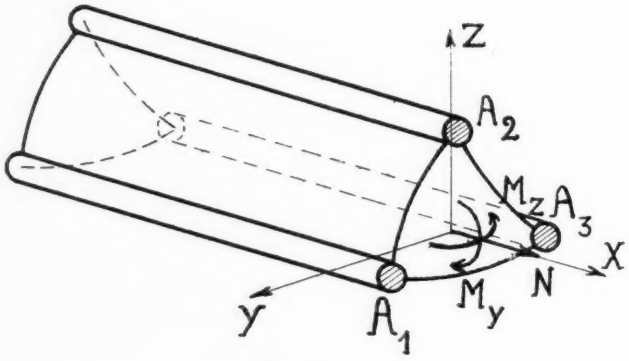

FIG. 5.

Moment of Inertia.—Let it be supposed that the y and z axes are the principal axes of the set (Fig. 4). The moment of inertia about O equals

$$i_o = \Sigma\, a_i \delta_i^2 = \Sigma\, a_i\, (d_i + z_o \cos \alpha_i - y_o \sin \alpha_i)^2$$
$$= i_g + z_o^2 a_y + y_o^2 a_z \qquad (24)$$

The moment of inertia about any point equals the moment of inertia about the centre of gravity plus the moments of the axes y and z bearing respectively the areas a_y and a_z. The moment of inertia about the centre of gravity is thus the minimum moment.

STATICALLY DETERMINATE BEAMS.

12. THE BEAM STATICALLY DETERMINATE IN EACH SECTION. STRESS OF THE FLANGES.

If the number of flanges does not exceed three, the normal force in each of them is statically determinate as a function of the total normal force and the bending moments in the section concerned.* If the principal axes Y and Z of the set of flanges are chosen as reference, the following relations hold (A = area):

$$\Sigma A_k Y_k = \Sigma A_k Z_k = \Sigma A_k Y_k Z_k = 0 \quad . \quad . \quad . \quad . \quad (25)$$

and, by definition,

$$A = \Sigma A_k, \quad I_Y = \Sigma A_k Z_k^2, \quad I_Z = \Sigma A_k Y_k^2 \quad . \quad . \quad . \quad . \quad (26)$$

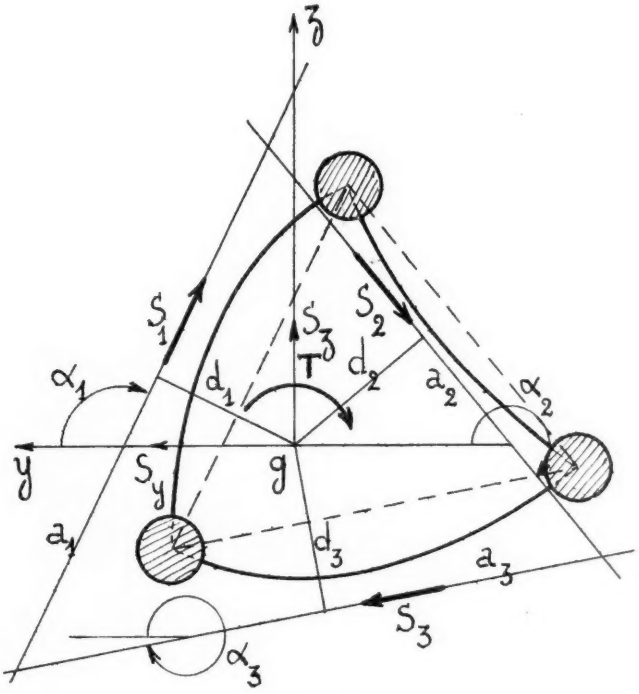

FIG. 6.

Let M_Y and M_Z be the bending moments about the Y and Z axes, considered as positive as shown by Fig. 5. The equilibrium of the section requires that (N = normal force)

$$N = \Sigma N_k, \quad M_Y = \Sigma N_k Z_k, \quad M_Z = \Sigma N_k Y_k \quad . \quad . \quad . \quad . \quad (27)$$

Solving these equations as regards N_k it is easily seen that

$$N_k = \frac{A_k}{A} N + \frac{A_k Z_k}{I_Y} M_Y + \frac{A_k Y_k}{I_Z} M_Z \quad . \quad . \quad . \quad (28)$$

Thus the normal force N is distributed between the flanges proportionally to their areas, and the bending moments proportionally to their static moments (*cf.* Eq. 5).

* Except if the flanges are coplanar.

13. Stress of the Webs.

In the same way, if the number of webs does not exceed three, the shear in each of them is statically determinate as a function of the total shears and of the twisting moment in the section concerned.*

If the principal axes y and z of the set of webs are chosen as reference, the following relations hold (Fig. 6):—

$$\Sigma\, a_i d_i \cos \alpha_i = \Sigma\, a_i d_i \sin \alpha_i = \Sigma\, a_i \sin \alpha_i \cos \alpha_i = 0 \quad . \quad . \quad (29)$$

and, by definition,

$$a_y = \Sigma\, a_i \cos^2 \alpha_i,\ a_z = \Sigma\, a_i \sin^2 \alpha_i,\ i = \Sigma\, a_i d_i^2 \quad . \quad . \quad (30)$$

Let S_y and S_z be the shears in the y and z directions, considered as positive when acting in the positive directions of the axes on the part of the beam located behind the section. The shears S_i in the webs are considered as positive when acting on the back part of the beam according to the positive sense of rotation (clockwise).

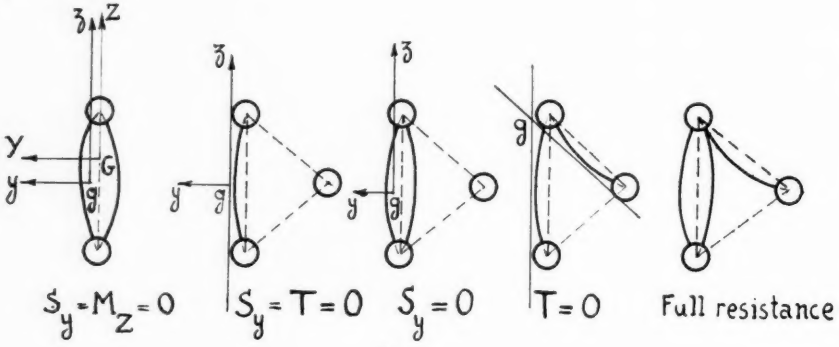

Fig. 7.

The equilibrium of the section requires that

$$S_y = \Sigma\, S_i \cos \alpha_i,\ S_z = \Sigma\, S_i \sin \alpha_i,\ T = \Sigma\, S_i d_i \quad . \quad . \quad . \quad . \quad (31)$$

Solving these equations as regards S_i it is easily seen that

$$S_i = \frac{a_i \cos \alpha_i}{a_y} S_y + \frac{a_i \sin \alpha_i}{a_z} S_z + \frac{a_i d_i}{i} T \quad . \quad . \quad . \quad (32)$$

The shears are distributed between the webs proportionally to the "projections" of the areas on their respective axes, and the twisting moment to the static moments.

14. Remark.

If the numbers of flanges and webs are less than three, the previous formulæ apply, but some total loads are necessarily zero. The single spar is a first example for which (Fig. 2)

$$M_z = S_y = T = 0$$

since

$$I_z = a_y = i = 0$$

Other examples are shown by Fig. 7.

15. The Other Statically Determinate Beams.

If the number of webs is not greater than three, the normal force in each flange can often be determined by statics only, even if the number of flanges exceeds three, provided that these forces are known in one section.

* Except if the webs are parallel.

Indeed, if, for instance, two webs i and $i+1$ are bound to the flange k (Fig. 8) the longitudinal equilibrium of an element is expressed by (*cf.* Eq. 8)

$$\frac{dN_k}{dX} = \tau_i t_i - \tau_{i+1} t_{i+1} = \frac{S_i}{h_i} - \frac{S_{i+1}}{h_{i+1}} \quad . \quad . \quad . \quad . \quad (33)$$

As soon as the shears in the webs are known the forces in the flanges are easily found by integration. Examples of this case are given by Fig. 9.

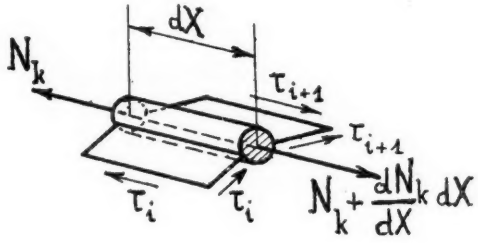

FIG. 8.

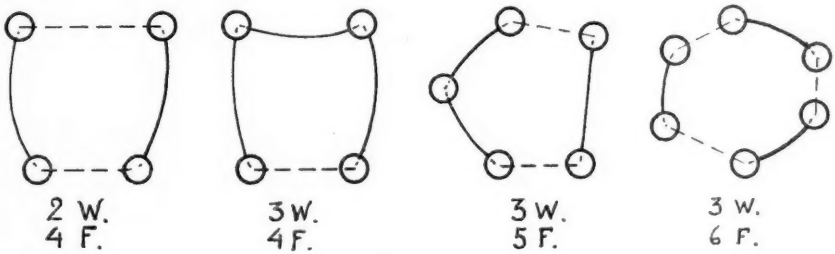

FIG. 9.

STATICALLY INDETERMINATE BEAMS.

16. REDUNDANCY.

In the other cases the stresses cannot be determined by statics only. But it is generally forgotten, and it must be emphasised that in most of the cases the structure is *not redundant*.

Statics are insufficient, not because some external loads can be carried by two separate parts of the structure and must be divided between them, but because the six total loads in each section, normal force, shears, bending moments and twisting moment, are unable wholly to define the state of loading. It is generally wanted that the state of stress should be completely determined as a function of those six loads. Therefore the structure is *made redundant* by assuming that it is stiffened by rigid bulkheads. Although it is not explicitly said, it is generally assumed that the beam is completely stiff in each section. *i.e.*, there is an infinity of elementary frames placed close to each other. Henceforth, the normal stresses cannot be determined still as functions of the total normal force and the bending moments only, nor the shear stresses as functions of the shears and twisting moment only.

In a few cases (see further) the interference between normal and shear stresses can be calculated without too many difficulties. But, in the more intricate cases one must limit oneself to either of following approximations :—

1. The deformation of the webs is negligible against that of the flanges.*

* This is the point of view adopted by R. S. Hatcher in " Rational Shear Analysis of Box Girders," Journal of the Aeronautical Sciences, Vol. 4, 1936-37, p. 233. See also Vol. 5, p. 369, and Vol. 6, p. 58.

2. The deformation of the flanges is negligible against that of the webs.

A well-defined distribution of stress (distribution of forces between the flanges and of stress between the webs) corresponds to each of the assumptions, and the true distribution of stress is something between these two distributions. In both cases it is assumed that one cross section at least remains plane.

17. Webs Infinitely Rigid. Stress in the Flanges.

The infinite rigidity of the webs is expressed by $G=\infty$. Since the shears are not infinite it follows from Eq. 16 that, for each web (Fig. 10)

$$-\frac{dr_i}{dX}=\frac{u_{k+1}-u_k}{h_i}$$

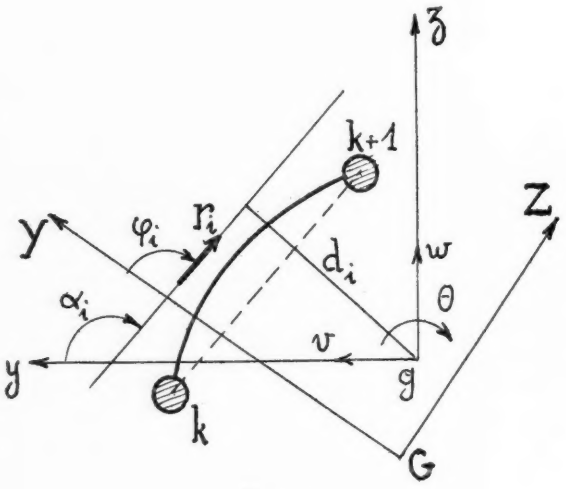

Fig. 10.

Since the cross section is rigid in its own plane, its movement consists of a translation v, w and a rotation θ.

$$r_i=v\cos\alpha_i+w\sin\alpha_i+d_i\theta \quad . \quad . \quad . \quad . \quad (34)$$

Thus the rotation in the plane of the web of the line joining k to $k+1$ in the cross section, equals

$$\frac{u_{k+1}-u_k}{h_i}=-\frac{dv}{dx}\cos\alpha_i-\frac{dw}{dx}\sin\alpha_i-d_i\frac{d\theta}{dx} \quad . \quad . \quad . \quad . \quad (35)$$

It will be supposed that the box beam is closed, *i.e.*, there are two webs joining each flange. Hence, for the whole section

$$\Sigma\, h_i\cos\alpha_i=\Sigma\, h_i\sin\alpha_i=0 \quad . \quad . \quad . \quad . \quad (36)$$

If the equations (35) are multiplied by h_i and added together, one gets

$$0=\Sigma\, h_i d_i\frac{d\theta}{dx}. \quad . \quad . \quad . \quad . \quad . \quad (37)$$

Since

$$\Sigma\, h_i d_i=2\,\Omega \quad . \quad . \quad . \quad . \quad . \quad (38)$$

Ω being the surface defined by the webs; the angle of torsion per unit length must be zero. The equation (35) shows then that the longitudinal displacements between the flanges are those which correspond to a rotation dv/dx in the xy

plane, and a rotation dw/dx in the xz plane. The cross section thus keeps plane and one may write, if the principal axes of the set of flanges are now used

$$u = u_G + \frac{\partial u}{\partial Y} Y + \frac{\partial u}{\partial Z} Z \quad . \quad . \quad . \quad . \quad . \quad (39)$$

The normal force in any flange equals

$$N_k = EA_k \frac{du_k}{dX} = EA_k \left[\frac{du_G}{dX} + Y_k \frac{\partial^2 u}{\partial X \partial Y} + Z_k \frac{\partial^2 u}{\partial X \partial Z} \right] . \quad . \quad . \quad (40)$$

Using the relations (25) to (27) it is easily shown that

$$\frac{du_G}{dX} = \frac{N}{EA} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

$$\frac{\partial^2 u}{\partial X \partial Y} = \frac{M_Z}{EI_Z} \qquad \frac{\partial^2 u}{\partial X \partial Z} = \frac{M_Y}{EI_Y} \quad . \quad . \quad (42)$$

and hence that the normal force in any flange takes the form (28)

The equation (41) shows that the extension along the X axis is proportional to the total normal force. Therefore the centre of gravity G may be called a *centre of traction*. The equations (42) show that the curvature about the Y and Z axes are proportional to the respective bending moments, and that each moment does not extend the beam along its own axis. The axes Y and Z are thus *axes of flexion* and their intersection is not only a centre of traction but also a *centre of flexion*. Those definitions hold for the beam statically determinate in each section, too.

Stress in the Webs.

Once the forces in the flanges are known, the shears in the webs are determined by the equations (33), the number of which equals the number of webs. But these equations are not independent of each other, so that the expressions S_i/h_i are determined to a constant. Let it be supposed that S_1^*, S_2^*, . . . is a set of values verifying the equations. They are independent of the shape of the webs. It is useful to remember that S/h equals the product of the shear stress by the thickness of the web (Eq. 7). If a constant "shearing force" $(S/h)_0$ is applied along the whole section of the webs, the equations still hold, and the twisting moment becomes

$$T = \Sigma\, d_i S_i^* + \left(\frac{S}{h}\right)_0 \Sigma\, h_i d_i = T^* + 2\,\Omega \left(\frac{S}{h}\right)_0 \quad . \quad . \quad . \quad . \quad (43)$$

This equation determines $(S/h)_0$ and hence the shear in each web

$$S_i = S_i^* + h_i \left(\frac{S}{h}\right)_0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

18. Flanges Infinitely Rigid. Stress in the Webs.

The infinite rigidity of the flanges is expressed by $E = \infty$. Since the forces in the flanges are not infinite it follows from Eq. 40 that, for each flange,

$$\frac{du_k}{dX} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

if the longitudinal displacement is zero in one section, it is zero along the whole length of the beam, and the shear in each web equals (Eq. 16 and 34)

$$S_i = Ga_i \frac{dr_i}{dx} = Ga_i \left[\frac{dv}{dx} \cos \alpha_i + \frac{dw}{dx} \sin \alpha_i + d_i \frac{d\theta}{dx} \right] \quad . \quad . \quad . \quad (46)$$

Using the relations (29) to (31) it is easily shown that

$$\frac{dv}{dx} = \frac{S_y}{Ga_y} \qquad \frac{dw}{dx} = \frac{S_z}{Ga_z} \quad . \quad . \quad . \quad . \quad (47)$$

$$\frac{d\theta}{dx} = \frac{T}{Gi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

and hence that the shear in any web takes the form Eq. 32.

The relations (47) show that the distortion in the xy and xz planes are proportional to the respective shears. Therefore the axes y and z are called *axes of shear* and their intersection is the *centre of shear*. The last equation shows that the angle of twist is proportional to the twisting moment about the centre of gravity g. Therefore the centre of shear is also a *centre of torsion*.

Those definitions hold for the statically determinate beam too, but while for this latter the centre of traction-flexion and the axes of flexion exist beside the centre of shear-torsion and the axes of shear, in the statically indeterminate beam the appearance of one set is the result of restrictive assumptions which remove the meaning of the other.

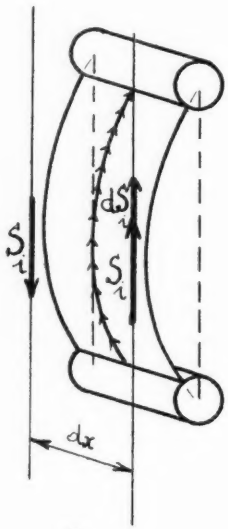

FIG. 11.

The coincidence of the centre of shear with the centre of torsion is not obvious and P. Cicala has shown that, in the solid beams, they are often distinct.* As yet the terminology about them is not agreed upon, and this contributes to the confusion.

STRESS IN THE FLANGES.

Once the shears in the webs are known, the equations (33) give the derivative of the force in each flange. If these forces are known in one section, they are found by integration along the whole length of the beam.

19. BULKHEADS.

As soon as the shears in the webs are known in every section it is easy to study the bulkheads. The assumption of an infinity of small bulkheads will be kept first. An element of web of length dx (Fig. 11) is in equilibrium in the plane of the cross section under the action of the shears on both ends, and the forces applied by the bulkhead to it. Since the shears are uniformly distributed along

* P. Cicala. Atti della Reale Accademia delle Scienze di Torino, Vol. **70**, **1934-35**.

the cross section of each web the forces applied by the web to the elementary bulkhead are distributed in the same way, and have a resultant dS_i excentrically applied.

If, as usual, the infinity of bulkheads corresponding to a certain length of the beam is replaced by one bulkhead of finite strength, this will have to carry all the loads of the removed elementary frames. The load applied by each web, and distributed along its cross section, to the bulkhead, equals the finite increase ΔS_i of the shear.

Since the web shears in each section balance the total shears and twisting moment, the increases of the shears correspond to the loads applied on the part of the beam under consideration. The first part played by the bulkheads is thus to distribute correctly among the webs the loads applied on the beam. But, even if no external loads are applied, the distribution of shears and twisting moment may change from one section to the other. In that case the bulkhead must play a second part in carrying shears from one web to the other.

The loads on the bulkheads are thus well known and they can be studied as usual plane frames. The only peculiarity is that the forces are distributed along the edges of the frame instead of being concentrated on some points, but this is not a hindrance. Since the bulkheads must transmit forces in their own planes, it seems that the most economical shape is the plane truss, though frequently the bulkheads are rigid-jointed frames, without diagonals.

20. Redundancy of the First Degree.

When only one relation is wanted in every section to find the state of stress and strain, the redundancy is of the first degree. But, instead of having a single redundant quantity, there is a redundant variable, which ought to be determined along the whole length of the beam. This case appears for the quadrangular box beam and for the wing with three spars.

Quadrangular Box Beam.

This kind of beam was correctly studied by L. Kirste.* But it seems useful to recall the calculation anew in the light of what has been previously said. Let the webs be called $i=1,\ 2,\ 3,\ 4$ (Fig. 12), and the flanges $12,\ 23,\ 34,\ 41=i,\ i+1$, and let the axes yz of the set of webs be used as reference.

21. Stress of the Webs.

Since the cross section is rigid in its own plane the movement of each web along its axis is given by Eq. 34. Hence the shear (Eq. 16) becomes

$$S_i = Ga_i\left[\frac{dv}{dx}\cos\alpha_i + \frac{dw}{dx}\sin\alpha_i + d_i\frac{d\theta}{dx} + \frac{u_{i,\,i+1}-u_{i-1,\,i}}{h_i}\right] \quad . \quad . \quad (49)$$

The total shears and the twisting moment on the whole section (Eq. 31) are, remembering Eq. 29 and 30,

$$\left.\begin{aligned} S_y &= Ga_y\frac{dv}{dx} + G\sum\frac{a_i}{h_i}(u_{i,\,i+1}-u_{i-1,\,i})\cos\alpha_i \\ S_z &= Ga_z\frac{dw}{dx} + G\sum\frac{a_i}{h_i}(u_{i,\,i+1}-u_{i-1,\,i})\sin\alpha_i \end{aligned}\right\} \quad . \quad . \quad (50)$$

$$T = Gi\frac{d\theta}{dx} + G\sum\frac{a_i d_i}{h_i}(u_{i,\,i+1}-u_{i-1,\,i}) \quad . \quad . \quad . \quad . \quad (51)$$

The longitudinal displacements of the flanges can be considered as resulting from a movement of the cross section as a whole and of a displacement of each

* L. Kirste. Sur le Calcul des poutres en caisson. l'Aérotechnique (Suppl. to l'Aéronautique), 1937, p. 1 and 57.

flange towards either side of the plane. The division is arbitrary and can be made in any useful way. Thus

$$u = u_g + y\frac{\partial u}{\partial y} + z\frac{\partial u}{\partial z} + \delta \quad . \quad . \quad . \quad . \quad . \quad (52)$$

Since

$$y_{i,\,i+1} - y_{i-1,\,i} = h_i \cos \alpha_i, \qquad z_{i,\,i+1} - z_{i-1,\,i} = h_i \sin \alpha_i \quad . \quad . \quad (53)$$

the sums in (50) and (51) become

$$\left.\begin{aligned} \Sigma \frac{a_i}{h_i}(u_{i,\,i+1} - u_{i-1,\,i}) \cos \alpha_i &= a_y \frac{\partial u}{\partial y} + \Sigma \frac{a_i}{h_i}(\delta_{i,\,i+1} - \delta_{i-1,\,i}) \cos \alpha_i \\ \Sigma \frac{a_i}{h_i}(u_{i,\,i+1} - u_{i-1,\,i}) \sin \alpha_i &= a_z \frac{\partial u}{\partial z} + \Sigma \frac{a_i}{h_i}(\delta_{i,\,i+1} - \delta_{i-1,\,i}) \sin \alpha_i \end{aligned}\right\} \quad . \quad (54)$$

$$\Sigma \frac{a_i d_i}{h_i}(u_{i,\,i+1} - u_{i-1,\,i}) = \Sigma \frac{a_i d_i}{h_i}(\delta_{i,\,i+1} - \delta_{i-1,\,i}) = iU \quad . \quad . \quad . \quad (55)$$

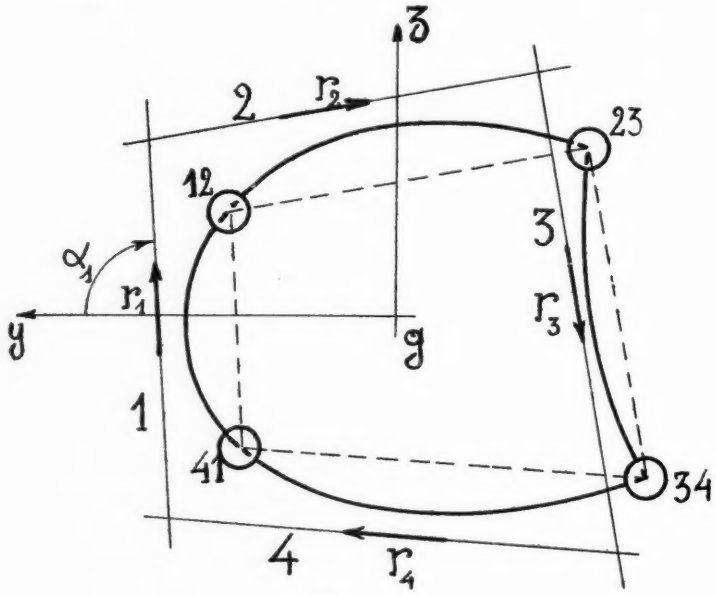

FIG. 12.

By choosing conveniently $\partial u/\partial y$ and $\partial u/\partial z$, *i.e.*, the slope of the plane which is considered as the mean plane of the cross section after deformation, it is possible to make

$$\Sigma \frac{a_i}{h_i}(\delta_{i,\,i+1} - \delta_{i-1,\,i}) \cos \alpha_i = \Sigma \frac{a_i}{h_i}(\delta_{i,\,i+1} - \delta_{i-1,\,i}) \sin \alpha_i = 0 \quad . \quad . \quad (56)$$

Henceforth it will be supposed that the mean plane has been so chosen. Thus the total shears become

$$\left.\begin{aligned} S_y &= Ga_y\left[\frac{dv}{dx} + \frac{\partial u}{\partial y}\right] = Ga_y\gamma_{xy} \\ S_z &= Ga_z\left[\frac{dw}{dx} + \frac{\partial u}{\partial z}\right] = Ga_z\gamma_{xz} \end{aligned}\right\} \quad . \quad . \quad . \quad (57)$$

calling γ_{xy} and γ_{xz} the distortions between the longitudinal axis and the mean plane of the cross section in the xy and xz planes.

The third sum (Eq. 55) is independent of the slope of the mean plane. It is thus zero if the cross section keeps plane, and depends only from the "*lack of level*" between the four flanges. Its quotient by i is called U. Thus the twisting moment becomes

$$T = Gi\left[\frac{d\theta}{dx} + U\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (58)$$

The equations (57) show that the axes y and z are still the axes of shear and that g is the centre of shear, but since U is introduced in Eq. 58, this point is no longer the centre of torsion.

The total shears and the twisting moment are expressed as functions of the distortions, the angle of twist and the lack of level. It is possible to express the shears in the web as functions of the same figures. Replacing u by (52) and taking notice of (57) the shear in the i web equals (*cf.* Eq. 49).

$$S_i = Ga_i\left[\gamma_{xy}\cos\alpha_i + \gamma_{xz}\sin\alpha_i + d_i\frac{d\theta}{dx} + \frac{\delta_{i,\,i+1} - \delta_{i-1,\,i}}{h_i}\right] \quad . \quad . \quad (59)$$

The four differences $\delta_{i,\,i+1} - \delta_{i-1,\,i}$ are determined by Eq. 55 and 56 and by the obvious relation

$$\Sigma\,(\delta_{i,\,i+1} - \delta_{i-1,\,i}) = 0 \quad . \quad . \quad . \quad . \quad . \quad (60)$$

It is easily seen that following values verify those four equations :—

$$\delta_{i,\,i+1} - \delta_{i-1,\,i} = -iU\frac{h_i}{a_i} - \frac{2\,\Omega h_i - \beta a_i d_i}{i\beta - 4\,\Omega^2} \quad . \quad . \quad . \quad . \quad (61)$$

with

$$\beta = \Sigma\frac{h_i^2}{a_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad (62)$$

if one remembers Eq. 38, 36, 30 and 29.

Consequently the shear in any web equals, if the distortions and the angle of twist are taken from (57) and (58)

$$S_i = a_i\cos\alpha_i\frac{S_y}{a_y} + a_i\sin\alpha_i\frac{S_z}{a_z} + a_i d_i\frac{T}{i} - 2\,\Omega GU\frac{ih_i - 2\,\Omega_i d_i}{i\beta - 4\,\Omega^2} \quad . \quad (64)$$

This expression should be compared with (32).

22. Stress of the Flanges.

The normal forces in the flanges must satisfy the three equations (27). A fourth equation is found by expressing the derivative of U. It follows from (55) and (40) that

$$iU' = \Sigma\frac{a_i d_i}{h_i}(u'_{i,\,i+1} - u'_{i-1,\,i}) = \frac{1}{E}\Sigma\frac{a_i d_i}{h_i}\left(\frac{N_{i,\,i+1}}{A_{i,\,i+1}} - \frac{N_{i-1,\,i}}{A_{i-1,\,i}}\right)$$

or, by re-arranging the terms,

$$iU' = \frac{1}{E}\Sigma\frac{N_{i,\,i+1}}{A_{i,\,i+1}}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1}d_{i+1}}{h_{i+1}}\right) \quad . \quad . \quad . \quad . \quad (65)$$

Solving equations (27) and (65) as regards $N_{i,\,i+1}$ $[k = (i, i+1)]$ and remembering (25) and (26) one gets

$$N_{i,\,i+1} = N\frac{A_{i,\,i+1}}{A} + M_y\frac{A_{i,\,i+1}Z_{i,\,i+1}}{I_y} + M_z\frac{A_{i,\,i+1}Y_{i,\,i+1}}{I_z} + \frac{EiU'}{R}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1}d_{i+1}}{h_{i+1}}\right) \quad (66)$$

(compare with 28) with

$$R = \Sigma\frac{1}{A_{i,\,i+1}}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1}d_{i+1}}{h_{i+1}}\right)^2 \quad . \quad . \quad . \quad . \quad (67)$$

It must be noticed indeed that

$$\Sigma\,Z_{i,\,i+1}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1}d_{i+1}}{h_{i-1}}\right) = \Sigma\,Y_{i,\,i+1}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1}d_{i+1}}{h_{i+1}}\right) = 0 \quad . \quad . \quad (68)$$

The first sum, rearranged, equals

$$\Sigma \frac{a_i d_i}{h_i} \cdot (Z_{i,\,i+1} - Z_{i-1,\,i})$$

If ϕ_i is the slope of the i web against the Y axis (Fig. 10),

$$Z_{i,\,i+1} - Z_{i-1,\,i} = h_i \sin \phi_i$$

and the sum is the projection on the Y axis (*cf.* Eq. 18) of the static moment of the set of webs, about g. It is thus zero. The same for the other sum.

23. Equation of U.

As soon as U is known in every section the shears in the webs are given by (64) and the forces in the flanges by (66). In order to find U it is enough to use one of the equations (33). It becomes, since N is supposed constant

$$\begin{aligned}\frac{A_{i,\,i+1} Z_{i,\,i+1}}{I_y} \cdot \frac{dM_Y}{dX} + \frac{A_{i,\,i+1} Y_{i,\,i+1}}{I_z} \frac{dM_Z}{dX} + \frac{EiU''}{R}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1} d_{i+1}}{h_{i+1}}\right) \\ = \frac{S_y}{a_y}\left(\frac{a_i \cos \alpha_i}{h_i} - \frac{a_{i-1} \cos \alpha_{i+1}}{h_{i+1}}\right) + \frac{S_z}{a_z}\left(\frac{a_i \sin \alpha_i}{h_i} - \frac{a_{i+1} \sin \alpha_{i+1}}{h_{i+1}}\right) \\ + \frac{T}{i}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1} d_{i+1}}{h_{i+1}}\right) + \frac{4\,\Omega^2 UG}{i\beta - 4\,\Omega^2}\left(\frac{a_i d_i}{h_i} - \frac{a_{i-1} d_{i+1}}{h_{i+1}}\right) \quad . \quad . \quad (69)\end{aligned}$$

The four equations of this type are equivalent to each other. A more symmetrical equation is obtained by multiplying them by

$$\frac{1}{A_{i,\,i+1}}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1} d_{i+1}}{h_{i+1}}\right)$$

and adding them together. Remembering (67) and (68) one gets

$$EiU'' - \frac{4\,\Omega^2 GR}{i\beta - 4\,\Omega^2} U = \frac{R}{i}[T + z_K S_y - y_K S_z] \quad . \quad . \quad . \quad (70)$$

with

$$\left.\begin{aligned} y_K &= -\frac{i}{Ra_z} \Sigma \frac{1}{A_{i,\,i+1}}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1} d_{i+1}}{h_{i+1}}\right)\left(\frac{a_i \sin \alpha_i}{h_i} - \frac{a_{i+1} \sin \alpha_{i+1}}{h_{i+1}}\right) \\ z_K &= +\frac{i}{Ra_y} \Sigma \frac{1}{A_{i,\,i+1}}\left(\frac{a_i d_i}{h_i} - \frac{a_{i+1} d_{i+1}}{h_{i+1}}\right)\left(\frac{a_i \cos \alpha_i}{h_i} - \frac{a_{i+1} \cos \alpha_{i+1}}{h_{i+1}}\right) \end{aligned}\right\} . \quad (71)$$

The sum within the brackets is the twisting moment T_K about the point the co-ordinates of which are y_K and z_K. This point will be called the *centre of distortion*. The equation of U is thus

$$U'' - \frac{G}{E} \frac{4\,\Omega^2 R}{i\,(i\beta - 4\,\Omega^2)} U = \frac{R}{Ei^2} T_K \quad . \quad . \quad . \quad (72)$$

24. Resolution.

The coefficient of U in that equation is always negative; thus a real length λ can be defined by

$$\lambda^2 = \frac{E}{G} \frac{i\,(i\beta - 4\,\Omega^2)}{4\,\Omega^2 R} \quad . \quad . \quad . \quad . \quad . \quad (73)$$

This length is usually variable along the beam, so that the exact resolution of the equation is very difficult. But it is easy to find a good approximation by dividing the beam into parts which are small enough to allow all quantities to be considered as constant. The general integral equals then

$$U = -\frac{R\lambda^2}{Ei^2} T_K + (A + B)\, e^{\frac{x - x_1}{\lambda}} + (A - B)\, e^{-\frac{x - x_1}{\lambda}}$$

In the neighbourhood of the section x_1, the exponentials may be replaced by the first terms of their developments

$$U = -\frac{R\lambda^2}{Ei^2}T_K + 2A + 2B\frac{x-x_1}{\lambda} + 2A\frac{(x-x_1)^2}{2\lambda^2} \quad . \quad . \quad (74)$$

If $(x-x_1)$ is limited to a fraction of λ (say $\frac{1}{2}$) the parabolic approximation will be sufficiently accurate.

Let the beam be divided in equal fractions of length Δx, Δx being smaller than one half the smallest value of λ (Fig. 13). The lack of level may be considered as a parabolic function along the length of two adjacent intervals. Let U_0, U_1, U_2, be its values in the sections of co-ordinates $x_1-\Delta x$, x_1, $x_1+\Delta x$. Between the limits of the interval

$$U = U_1 + \frac{U_2-U_0}{2\Delta x}(x-x_1) + \frac{U_2-2U_1+U_0}{2(\Delta x)^2}(x-x_1)^2 \quad . \quad . \quad (75)$$

Equating both expressions of U

$$2A = U_1 + \frac{R\lambda^2}{Ei^2}T_K = (U_2-2U_1+U_0)\left(\frac{\lambda}{\Delta x}\right)^2$$

Hence

$$U_2-U_1 = \frac{R(\Delta x)^2}{Ei^2}T_K + U_1\left[1+\left(\frac{\Delta x}{\lambda}\right)^2\right] - U_0$$

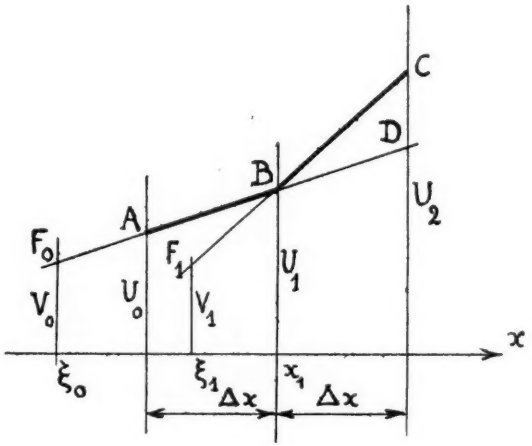

FIG. 13.

If the chord AB passes through a fixed point F_0, the chord BC passes through another fixed point F_1. Let ξ_0 and V_0 be the co-ordinates of F_0. The equation of AB is

$$U = V_0 + n(x-\xi_0)$$

and the ordinates U_0 and U_1 equal

$$U_0 = V_0 + n(x_1-\Delta x-\xi_0)$$
$$U_1 = V_0 + n(x_1-\xi_0).$$

Thus

$$U_2-U_1 = \frac{R(\Delta x)^2}{Ei^2}T_K + V_0\left(\frac{\Delta x}{\lambda}\right)^2 + n\Delta x\left[(x_1-\xi_0)\frac{\Delta x}{\lambda^2}+1\right]$$

and the equation of chord BC is

$$U-U_1 = \frac{x-x_1}{\Delta x}(U_2-U_1)$$

or

$$U = V_0 + \frac{x - x_1}{\Delta x}\left[\frac{R\,(\Delta x)^2}{Ei^2} T_K + V_0\left(\frac{\Delta x}{\lambda}\right)^2\right]$$
$$+ n\left[x_1 - \xi_0 + (x - x_1)\left\{1 + (x_1 - \xi_0)\frac{\Delta x}{\lambda^2}\right\}\right]$$

The ordinate is independent of n in the section defined by

$$(x_1 - \xi_0) + (x - x_1)\left\{1 + (x_1 - \xi_0)\frac{\Delta x}{\lambda^2}\right\} = 0$$

Let ξ_1 be the value of x thus found

$$x_1 - \xi_1 = \frac{x_1 - \xi_0}{1 + (x_1 - \xi_0)\,\Delta x\,\lambda^2} \quad . \quad . \quad . \quad . \quad (76)$$

The ordinate V_1 of the chord BC in this point is given by

$$V_1 - V_0 = \frac{\xi_1 - \xi_0}{x_1 - \xi_0}\left(-\frac{R\lambda^2}{Ei^2} T_K - V_0\right) \quad . \quad . \quad . \quad (77)$$

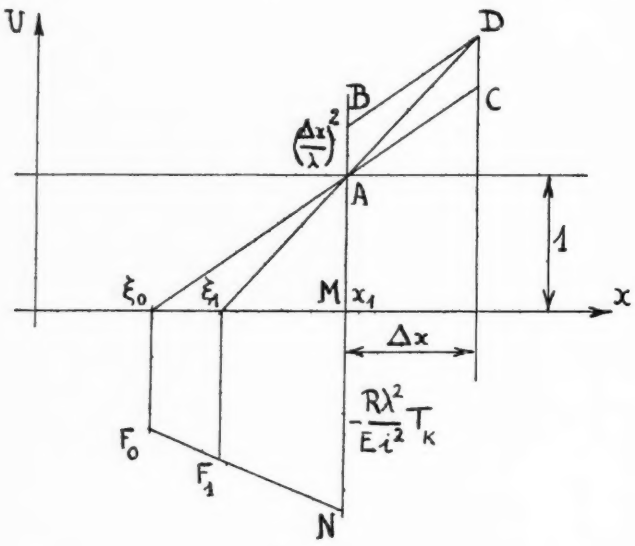

FIG. 14.

It must be pointed out that the abscissæ of the fixed points do not depend on the state of loading, but only on the geometrical properties of the beam. They are found successively as shown by Fig. 14. A horizontal line or ordinate 1 is drawn, an $(\Delta x/\lambda)^2$ is measured upwards from that line in AB. Point A is joined to the point of the x axis of the abscissa ξ_0 and the length AB is marked off as CD. Intersection of AD with the x axis gives the abscissa ξ_1.

Now, if the ordinate V_0 of the first fixed point F_0 is known, B_1 is found by drawing $-(R\lambda^2/Ei^2)\,T_K$ in MN. Point F_0 is joined to N, and the second fixed point F_1 lies on this straight line.

25. LIMIT CONDITIONS.

Since the differential equation is of the second order two limit conditions are required. Usually they will be of either following kind:

1. If the lack of level is known in one section (*e.g.*, if it is zero, the section being stiffly built-in), the U-curve passes through a given point which is, of course, one of the fixed points.
2. If the distribution of the normal forces is known in one section, the derivative of U is known (Eq. 65); that means that the chord of the U curve has a given direction and that the fixed point is at infinite distance in that direction.

The resolution has been carried out on Fig. 15 with the assumption that $U=0$ at the left end and $U'=0$ at the right end. First, the abscissæ of the fixed points are found, starting from ξ_0, which is known; then their ordinates, starting from F_0 which is known. Since $\mathbf{U}'$ is zero at the right end the last chord is drawn horizontally through F_4. Joining the left end of it to F_3 one has the next chord, and so on.

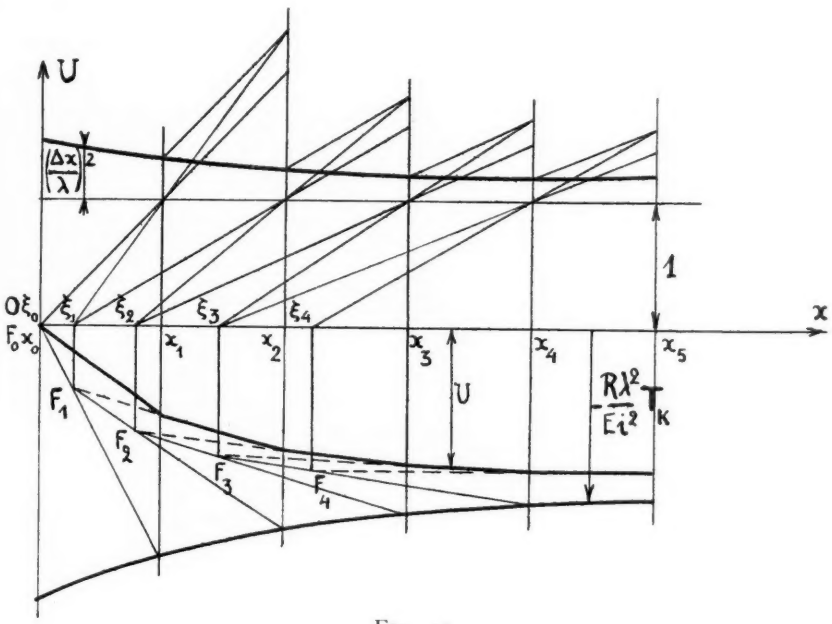

FIG. 15.

26. REMARKS.

Dividing the length of the beam in a reasonable number of parts, if $(\Delta x/\lambda)^2$ is small compared to unity, it is difficult to find the fixed points with accuracy. They lie very near each other. The result is the same as it would be if E were very great (Eq. 73), *i.e.*, when the strain of the flanges is negligible. This case has been studied before.

On the other hand, if λ is so small that, to keep $(\Delta x/\lambda)^2$ sufficiently small it would be necessary to divide the beam into too many parts, the result is the same as if G were very great. This is the second limit case contemplated before. It is worth noticing that in both limit cases $U=0$ along the whole length.

27. BULKHEADS.

As soon as U, and consequently U' is known in every section, the shears in the webs (Eq. 64) and the forces in the flanges (Eq. 66) are known. The loads

on the bulkhead equal the increases of shears between the two sections limiting the concerned part of the beam (*cf.* para. 19).

The increase of shear in the i web equals (Eq. 64)

$$\Delta S_i = \frac{a_i \cos \varkappa_i}{a_y} \Delta S_y + \frac{a_i \sin \varkappa_i}{a_z} \Delta S_z + \frac{a_i d_i}{i} \Delta T - 2\, G\Omega \Delta U \frac{i h_i - 2\,\Omega a_i d_i}{i\beta - 4\,\Omega^2} . \qquad (78)$$

The first three terms of this expression correspond to the externally applied loads. The bulkhead has to distribute them. The last term correspond to loads the resultant of which, for the whole section, is zero. They are the shears transposed from one web to the other.

Among the increases of U along the beam must not be forgotten that at the free end of a cantilever beam; since just before the end U is generally not zero, and just past it it is zero ($a_i = 0$, Eq. 55) there is a discontinuity in the value of U which requires the presence, at the end of the beam of a bulkhead of finite strength.

Wing with Three Spars.

28. Stress of the Webs.

The wing whose main structure consists of three spars with parallel webs presents also a redundancy of the first degree since the problem is solved as soon as the shear in one web, for instance, is known (Fig. 16).

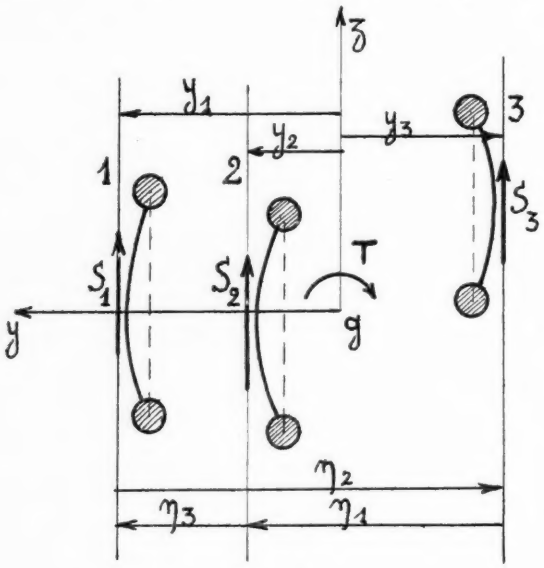

Fig. 16.

Since the webs are parallel and vertical the structure is unable to withstand flexion (bending moment and shear) in the horizontal plane. Moreover it will be supposed that the total normal force acting on each spar and, hence, on the whole beam, is zero.

The position of the centre of gravity g of the webs is vertically indeterminate. Horizontally it is defined by

$$\Sigma\, y_i a_i = 0 \qquad . \quad . \quad . \quad . \quad . \qquad (79)$$

There is only one total area of the webs, directed vertically

$$a_z = \Sigma\, a_i, \quad a_y = 0 \qquad . \quad . \quad . \quad . \quad . \qquad (80)$$

The shears in the webs must verify the equations

$$\Sigma S_i = S_z, \qquad \Sigma y_i S_i = T \quad . \quad . \quad . \quad . \quad (81)$$

The general solution of these two equations is (*cf.* 64)

$$S_i = \frac{a_i}{a_z} S_z + \frac{a_i y_i}{i} T + U (y_{i+1} - y_{i-1}) \quad . \quad . \quad . \quad . \quad (82)$$

For the sake of simplicity the difference

$$y_{i+1} - y_{i-1} = \eta_i \quad . \quad . \quad . \quad . \quad . \quad (83)$$

will be called η_i (Fig. 16), and U will be called as previously lack of level, though it has now another meaning. It is obvious that

$$\Sigma \eta_i = \Sigma \eta_i y_i = 0 \quad . \quad . \quad . \quad . \quad . \quad (84)$$

29. Stress of the Flanges.

The movement of each web along its axis equals, since the shape of the section is constant (*cf.* 34),

$$r = w + y_i \theta \quad . \quad . \quad . \quad . \quad . \quad (85)$$

Applying Eq. 16 to each spar and calling Δu_i the difference between the displacements of the upper and lower flanges, one gets

$$\frac{\Delta u_i}{h_i} = \frac{S_i}{G a_i} - \frac{dr}{dx} = \frac{1}{G}\left[\frac{S_z}{a_z} + \frac{y_i T}{i} + \frac{\eta_i U}{a_i}\right] - \left[\frac{dw}{dx} - y_i \frac{d\theta}{dx}\right] \quad . \quad . \quad (86)$$

Deriving and applying Eq. 13,

$$\frac{1}{h_i}\frac{d\Delta u_i}{dx} = \frac{M_i}{E I_i} = \frac{1}{G}\left[\frac{S_z'}{a_z} + \frac{y_i T'}{i} + \frac{\eta_i U'}{a_i}\right] - \left[\frac{d^2 w}{dx^2} + y_i \frac{d^2\theta}{dx^2}\right] \quad . \quad (87)$$

30. Equation of U.

Deriving once more and remembering that, in each spar, the derivative of the bending moment is the shear:

$$\frac{S_i}{E I_i} = \frac{1}{E I_i}\left[\frac{a_i}{a_z} S_z + \frac{a_i y_i}{i} T + U \eta_i\right]$$

$$= \frac{1}{G}\left[\frac{S_z''}{a_z} + \frac{y_i T''}{i} + \frac{\eta_i U''}{a_i}\right] - \left[\frac{d^3 w}{dx^3} + y_i \frac{d^3\theta}{dx^3}\right] . \quad . \quad . \quad (88)$$

If the expressions $S_z'' / G a_z - d^3 w / dx^3$ and $T'' / G i - d^3\theta / dx^3$ are eliminated between the three equations of this type there remains a differential equation of the second order which reads:

$$\frac{U''}{G} \Sigma \frac{\eta_i^2}{a_i} - \frac{U}{E} \Sigma \frac{\eta_i^2}{I_i} = \frac{S_z}{E a_z} \Sigma \frac{a_i \eta_i}{I_i} + \frac{T}{E i} \Sigma \frac{a_i y_i \eta_i}{I_i}$$

Let y_K be

$$y_K = -\frac{i}{a_z}\left[\Sigma \frac{a_i \eta_i}{I_i} : \Sigma \frac{a_i y_i \eta_i}{I_i}\right] \quad . \quad . \quad . \quad . \quad (89)$$

the equation becomes

$$\frac{U''}{G} \Sigma \frac{\eta_i^2}{a_i} - \frac{U}{E} \Sigma \frac{\eta_i^2}{I_i} = \frac{1}{E i} \Sigma \frac{a_i y_i \eta_i}{I_i}\left[T - y_K S_z\right] . \quad . \quad . \quad (90)$$

The sum in the brackets is the twisting moment about a point of co-ordinate y_K (z_K being indeterminate) (*cf.* Eq. 70).

The equation is solved exactly in the same way as Eq. 72.

31. Limit Conditions.

The limit conditions are similar to those previously encountered. If the distribution of shear is known in one section, U is known. It is easily derived from Eq. 82 that

$$U \Sigma \frac{\eta_i^2}{a_i} = \Sigma \frac{\eta_i S_i}{a_i} \quad . \quad . \quad . \quad . \quad . \quad (91)$$

If the distribution of the bending moment is known in one section, it follows from Eq. 87 that

$$\frac{U'}{G} \Sigma \frac{\eta_i^2}{a_i} = \frac{1}{E} \Sigma \frac{\eta_i M_i}{I_i} \quad . \quad . \quad . \quad . \quad (92)$$

and that U' is known.

At the free end of a cantilever beam both U and U' are zero, if no load is applied to that section.

As soon as U is known in every section, the shear in each web is given by Eq. 82. The bending moments are found by integration.

The loads applied to the ribs are determined as previously. As the bulkheads in the box beam, the ribs have to play two parts: distribute correctly the external loads, and carry shears from one web to the other.

Conclusion.

The problem of the box beam can be reasonably approached if convenient assumptions are made. Discussions have been raised, for instance, about the existence or non-existence of the shear centre,* the degree of redundancy, etc. The author hopes that this note brings an end to them.

The theory can be improved by taking into account the taper of the beam, but it is likely that the calculations would become very intricate.

One of the main conclusions is that the theory of Barré de St. Venant does not apply to the cross section of a box beam considered as a whole, and that the distribution of normal stress is linear only if restrictive assumptions are made. These are not compulsory if the redundancy is of the first degree. In the other cases the problem cannot be treated without simplification, but other assumptions, leading to a non-linear distribution of the normal stress are as reasonable as them.

The part played by the transverse frames is well defined, and their design must not at all be left to a subjective appreciation. Though not very strong against the main parts of the beam they are essential, especially when the beam is statically indeterminate.

* Z. Leliwa-Krzywoblocki. L'Aérotechnique (suppl. to l'Aéronautique) **1938**, p. **85**.

REVIEWS.

TEACH YOURSELF TRIGONOMETRY.

P. Abbott. English Universities Press, London. 1940. 2/6 net.

This is one of the series of "Teach Yourself" books issued by the English Universities Press. Nearly thirty volumes have now appeared, ranging from "Teach Yourself Good English" to "Teach Yourself Biology." They are excellent volumes for their purpose, and this latest one on trigonometry should prove invaluable to that growing number of people who are eager to learn all they can, but who are prevented, by circumstances, from learning through recognised educational centres.

In general, with the volumes in the series, it has been assumed that there is no previous knowledge of the subject, so each book is self-contained. In this particular book, however, it is clear that some knowledge of arithmetic and algebra must be assumed. All the acquaintance required in these subjects may, however, be obtained from a companion volume in the series "Teach Yourself Mathematics." The necessary amount of geometry required is included in the present book.

"Teach Yourself Trigonometry" goes as far as the solution of simple trigonometrical equations. Every term used is not only most carefully defined, but what is more important, is explained and illustrated by examples. Worked out examples are a feature of the text and miscellaneous examples for the student to work out are given at the end of each chapter, with a set of answers at the end of the book.

This is an excellent introduction to a subject which is of vital importance to all who have to fly and have a knowledge of navigation.

ENGINEERING ECONOMICS (BOOK I), WORKS ORGANISATION AND MANAGEMENT.

By T. H. Burnham and G. O. Hoskins. Sir Isaac Pitman and Sons, Ltd. 1940. 10/6 net.

This is the first volume, now in its Fifth Edition, dealing with Engineering Economics, works organisation and management. The volume under review is concerned primarily with the elements of industrial organisation.

To parody Rudyard Kipling, what can they know of engineering who only engineering know? How bitter is the truth of this may be judged by the fact that although engineers believe themselves to be the salt of the earth, like the salt they only appear on the side of the industrial plate. The engineers have only themselves to blame that they are not more in charge, that there is, for example, no engineer on the Air Council of the Royal Air Force, a highly technical service if there ever was one, that the chief engineer of a firm is seldom on the directorate, that the selling and business side of an engineering organisation is better paid than the engineering side.

Many engineers are waking up to the importance of a thorough understanding of engineering economics. This specially applies to the Executives and a book of this kind is one which will be of the utmost value to them. It begins with a brief summary of the meaning of Economics. Chapter II is concerned with money, banking and exchange. The function of banking is one which must be thoroughly grasped and it will save many Executives much time and controversy if they realise exactly what banks can and cannot do.

Chapter III covers the vital role played by mineral products which are the basis of engineering construction. It shows clearly the distribution of metallic ores throughout the Empire and the world. It is comforting to read that of the 28 leading metals and minerals, the British Empire has an abundance of no fewer than 21, can meet its own needs as regards two, is partially dependent for one and only dependent on foreign sources for four. Of the 28, coal, iron and petroleum in their total production exceed by four times that of the remainder put together. Petroleum, unfortunately, is one of those minerals upon which the Empire depends almost entirely on foreign countries, as is also the case with mercury and sulphur.

Chapter IV deals with the industrial revolution from the time of the early Guilds to the great changes which have been brought about by the machine age. The main feature of the evolution of industry is the acceleration of activity, productivity and invention.

Chapter V covers business organisation as partnership, joint stock companies, and so on, and is followed by a chapter on the Trade Cycle. The causes of booms and slumps are explained and their effect upon the rise of such forms of Government as Fascism.

Chapter VII is one of the really important chapters in the book and is concerned with the use of statistics in management.

Chapters VIII and IX deal with the legal side of business and Chapter X with the relationship of employers and workers.

The reviewer would recommend all engineering executives to pay careful and special attention to Chapter XI on the importance of research and development work in industry, the side of engineering which is really only now being appreciated. The chapter ends up with the statement " research is not supported by industry—industry is supported by research," a vital difference often overlooked.

The psychological factors of the function of management are dealt with in Chapter XIV.

This volume of " Engineering Economics " will be of very real value to all engineers and particularly to those who are taking examinations in this subject. One looks forward with a great deal of interest to the publication of Volume II which will deal with Works Organisation and Management.

THE ROYAL AERONAUTICAL SOCIETY
WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

MONTHLY NOTICES

FEBRUARY, 1941.

Nominations for Council.

Attention is drawn to Rules 68-85 regulating the constitution of the Council, and in particular to Rules 79 and 81, which read as follows:—

RULE 79.—One half of the Council (excluding the President and the Immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 85. Retiring members of Council who have served two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

RULE 81.—Nominations of Candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must each be entitled to vote in the R.Ae.S.

Under Rule 105 the Annual General Meeting is held at some convenient date before the end of March of each year, so that nominations must be received during the first week in March, and preferably by March 1st at the latest.

Annual General Meeting.

The Annual General Meeting of the Society will be held in the Society's Offices at 4, Hamilton Place, London, W.1, at the end of March. Notices will be sent to all voting members giving full particulars.

Members' Subscriptions.

Members are reminded that their subscriptions were due on January 1st, 1941. The Council hope that every member will make an effort to pay his subscription as early as possible to save postage on reminders. The rates are:—

	Home. £ s. d.	Abroad. £ s. d.
Founder Member	2 2 0	2 2 0
Fellow	4 4 0	3 3 0
Associate Fellow	3 3 0	2 2 0
Associate	*2 2 0	*2 2 0
Graduate	2 2 0	(21-26 years)
	2 12 6	(26-28 years)
Student	1 1 0	1 1 0
Companion	2 2 0	2 2 0

* £1 1s. 0d. without Journal.

Election of Members.

The following Members were recently elected:—

Associate Fellows.—Owen Hugh Dunon Blomfield, Keith Beaumont Chamberlain (from Graduate), Thomas Edmond John Fitton, Geoffrey Patrick Hebden (from Graduate), Willis Wood Richardson.

Associates.—Guy Bristow, Edward Spurr, Harold Frederick Stowell, Herbert David Borrett Taylor (from Student).

Graduates.—David William Kew (from Student), Percy Reginald Levy, Guy Bryan Probert, Claude Whittard Slatter (from Student).

Students.—Michael Gordon Kidston Byrne, Kenneth William Campbell, Alexander Gordon Farries, Ernest Charles Clear Hill, John Philipp Milford Reid, Charles Edwin Smith, Donald Bull Swinbanks, Peter Hayward Wall, Frank Cutts-Watson.

Companions.—Percy George Atkinson Boustead, Mary Katharine Beauchamp Harwood.

Leverhulme Research Fellowship, 1941.

Applications are invited for Fellowships and Grants in aid of research. The Fellowships or Grants are intended for senior workers who are prevented from carrying out research work by routine duties or pressure of other work. They are limited to British born subjects normally resident in Great Britain. In exceptional circumstances the Trustees may waive the condition as to residence. The Trustees are also prepared to consider applications from groups of workers engaged upon co-operative programmes of research—particularly from those engaged upon long-distance programmes or in Institutions in which the normal facilities for research have been curtailed by the War. Forms of application may be obtained from the Secretary, Dr. L. Haden-Guest, M.C., M.P., Leverhulme Research Fellowships, Kingscote House, 1, Watergate, Blackfriars, London, E.C.4.

Binding of Journals.

Arrangements have been made for Members' Journals to be bound at the special price of 4s. 6d. per volume for the current volume and 5s. 6d. for back volumes. Journals should be sent direct to the Lewes Press, Limited, Friars Walk, Lewes, Sussex, and a remittance to the Society.

New Year's Honours' List.

It is regretted that the honour awarded to Dr. R. A. Watson Watt was given incorrectly in the January Journal. Dr. Watt had the honour of the C.B. conferred on him, and not the G.C.B. as stated.

Acknowledgments.

The Council have recently received from Mr. Geoffrey Smith, Managing Director of *Flight* and allied publications, a large collection of very interesting aviation magazines for the Library. These papers fill many gaps in the Society's own collection and are greatly appreciated. Mr. H. R. Trost has also presented a number of periodicals and technical papers to the Library. It is desired to place on record the grateful thanks of the Society to these two donors.

Additions to Library.

(Pamphlets in italics, with location reference following in brackets. Books marked * may not be taken out on loan.)

*B.g.89.—I Cento Aeroplani Caproni: 1909-1930. By T. L. Barbero. "Aeronautica," Milan, 1930.

*B.g.90.—Jane's All the World's Aircraft. Edited by C. G. Grey and Leonard Bridgman. 1939.

D.b.133.—Imperial Airways: a Survey of its Organisation. (Issued for the Inauguration of Empire Air Mail to the Far East, July, 1938.)

E.c.7.—Relaxation Methods in Engineering Science. By R. V. Southwell. Clarendon Press, Oxford. 1940. 17/6.

EE.c.61.—Internal Combustion Engineering. Edited and Revised by A. T. J. Kersey. Blackie and Son. 1940. 17/6.

*G.b.32.—*Equivalent British and S.A.E. Nickel Alloy Steels. Mond Nickel Co.* 1940. (File Case, Section G.e.C.)

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L.d.61 and 62.—The Observer's Book on Astro-Navigation. (Parts 1 and 2.) By Francis Chichester. Allen and Unwin. 1941. 2/6 each part.

Q.d.45.—The Shipping Industry of Japan. Japan Economic Federation. 1940. 1/4.

R.f.62.—*Almanach* 1938 *de "L'Aviation Belge." Frs.* 5. (Y.11.iv.20.)

T.a.80.—*The Life and Work of the Late Sir Robert A. Hadfield, Bt., F.R.S. Hadfield's, Ltd. (Reprint from "The British Steelmaker.")* 1940.

U1.3.—*Scientific Papers of the Institute of Physical and Chemical Research, Tokyo. Nos.* 996-1,000. 1940.

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Also the following books, pamphlets, etc., presented by Mr. H. R. Trost:—

B.a.67.—Grossflugzeuge. By Günther Bock. Vandenhoeck and Ruprecht. 1931.

BB.c.74-76.—Junkers Verstell-Luftschrauben. Bauart Hamilton. (Three maintenance and operation handbooks. 1936-37.)

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D.a.B.68-79.—Air Ministry Reports on Progress of Civil Aviation. (1919-37.)

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Y.33.—Box-File containing 67 pamphlets, articles and reprints (some in English, but most in German) on Junkers aircraft, engines, organisation, etc.

12 boxes of Junkers catalogues and technical information.

22 Vols. Manufacturers' schedules of Junkers Aircraft, illustrated by photographs.

Three large and five small albums with photographs of Junkers aircraft.

J. Laurence Pritchard, *Secretary and Editor.*

FURTHER DEVELOPMENT OF A BOUNDARY LAYER PROFILE FOR A GIVEN PRESSURE DISTRIBUTION.*

By H. Görtler.

Translated by K. M. M. Goggin, B.Sc.

Air Ministry Translation No. 1051.†

4th July, 1940.

The following paper forms a continuation of a recent work by Prandtl (1) "On the Calculation of Boundary Layers." It deals with the problem of developing in detail the method, proposed in that paper, for continuing a given velocity profile in a laminar boundary layer when the pressure distribution is given; the method is tried out in practice by numerical evaluation of an example.

I. General Presentation of the Method.

1. Introduction.

In the case of steady, two-dimensional flow, which alone is of interest here, and assuming large values of Reynolds number, the following differential equations are known to apply to the laminar boundary layer:—

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+\frac{1}{\rho}\frac{dp}{dx}=\nu\frac{\partial^2 u}{\partial y^2} \quad . \quad . \quad . \quad . \quad . \quad (1.1)$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.2)$$

In these equations x denotes the arc length measured in the direction of flow along the wall from the front stagnation point, and y is the vertical distance from the wall. The known solutions of these equations for a given pressure distribution $p(x)$, which are to be found in the Göttingen theses of Blasius (3) 1907 and Hiemenz (4) 1911, which form continuations of Prandtl's (3) (1904) original paper, consist in expansions in powers of x; these have to be broken off after a few terms on account of the difficulty in numerically calculating the coefficients depending on y. When using a series expansion of this kind one is thus compelled to come to a standstill at somewhere about half way between the front stagnation point, $x=0$, and the required separation point, $x=x_A$, and to look around for a new method which will enable a further continuation of the boundary layer profile $u(x, y)$ from this position $x=x_0$ up to the separation point. Several different methods have been proposed and tried out up to the present; we will only refer here to Howarth's (5) comprehensive summary.

In the method which is to be developed in the following paper, the procedure is briefly as follows:—An expression for $\partial u/\partial x$, deduced from the differential equations for the boundary layer, is used for further continuation of the velocity profile $u(x_0, y)$, which is known numerically at $x=x_0$, in the direction of flow; however, this expression is not applicable in immediate proximity to the wall on account of the double differentiation with respect to y which is necessary but not reliable in that region, and also on account of the singularities which occur

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due to infringement of the known boundary layer relationships (Grenzschicht-Bindungen)* at the wall. These difficulties are overcome by additional series expansions in terms of the distance y from the wall; the coefficients of this series are determined from the aforementioned " Bindungen "; the series, which can be broken off after a finite number of terms, permits reliable differentiation with respect to y over a sufficiently large range $0 \leqq y \leqq y_a$, and thus does away with all difficulties in the neighbourhood of the wall.

2. The Method in Detail.

In the following the method will be given in detail, because it was found necessary to make certain alterations from Prandtl's fundamental ideas; a numerical example is given later.

.1. The basis for the whole method of further continuation of a boundary profile in the direction of flow is the following expression (6) deduced from (1.1), (1.2), and known from the beginning of the boundary layer theory:—

$$\frac{\partial u}{\partial x} = \frac{\partial}{\partial y}\left[u \int_{y_0}^{y} \frac{1}{u^2} \left\{ \nu \frac{\partial^2 u}{\partial y^2} - \frac{1}{\rho}\frac{dp}{dx} \right\} dy + u \cdot \phi(x) \right] \quad . \quad . \quad (2.1)$$

where $\phi(x)$ is a quantity occurring in the integration and depending on choice of the lower limit $y_0(x)$:—

$$\phi(x) = \frac{dy_0}{dx} = \left\{ \frac{v}{u} \right\}_{y=y_0} \text{ in particular } \phi(x) \equiv 0 \text{ when } y_0 \equiv 0.$$

As is well known (7), the requirement for regularity of the integral occurring in (2.1) states that along the wall $y=0$ the " boundary layer Bindungen " must be fulfilled; the first of these run:—

$$\nu \frac{\partial^2 u}{\partial y^2} = \frac{1}{\rho}\frac{dp}{dx}, \qquad \frac{\partial^3 u}{\partial y^3} = 0, \ldots,$$

and they state in general that at positions $v=0$ only the 1st, 4th, 7th . . . differential coefficients of the velocity profile $u(x, y)$ with respect to y can be freely selected. We shall have to deal in detail with these " Bindungen " in another form. At present it will merely be shown that, in order to be suitable for purposes of practical calculation, the expression (2.1) requires particularly careful treatment at the point at which differentiation of a numerically stated velocity profile $u(x_0, y)$ with respect to y must become inaccurate, namely, at the one end $y=0$ of the profile.

In order to solve the continuation problem another expression (8) was proposed in place of (2.1), having no less unsuitable properties at the point where u passes through zero:—

For the " total *pressure*—or *head* "

$$g = p + \frac{\rho u^2}{2}$$

the following differential equation is obtained from (1.1), (1.2):—

$$\frac{\partial g}{\partial x} = \mu u \frac{\partial^2 g}{\partial \psi^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.2)$$

in which the stream function ψ (for which $u = \partial\psi/\partial y$, $v = -\partial\psi/\partial x$) has been introduced in place of y as an independent variable in addition to x. In this form the boundary layer differential equation is particularly suitable for general discussion, on account of its relationship with the differential equation for heat conduction; however, for our purpose the behaviour at the wall causes difficulties

$$\left(u \to 0, \frac{\partial g}{\partial x} \to \frac{dp}{dx} \neq 0, \text{ therefore } \frac{\partial^2 g}{\partial \psi^2} \to \infty \right).$$

* " Grenzschicht Bindungen " is the term employed to denote the relationship between the functions expressing the velocity and pressure profiles at the wall. In the following the word " Bindung " has been retained.

In the case of both (2.1) and (2.2) a second differentiation is necessary, but with (2.2) a new source of error arises at each step due to the unnecessarily complicated conversion of ψ to y and y to ψ, as well as to occasional interpolation to equi-distant sub-divisions, in order to fit in the auxiliary method, which has yet to be described, consisting of a power series in terms of y from the wall, into the continuation method. We have therefore given the preference to the expression (2.1).

B. From the first it appeared suitable, as a counterpart to Blasius' expression as described above (a power series in terms of x with coefficients depending on y), to use a power series in terms of y.

$$u(x, y) = \sum_{\nu=1}^{\infty} a_\nu \frac{y^\nu}{\nu!} \quad . \quad . \quad . \quad . \quad (2.3)$$

whose coefficients a_ν are functions of x. When this expression is substituted in (1.1) and coefficients are compared, this again leads to the boundary layer "Bindungen." If we put

$$\frac{1}{\rho}\frac{dp}{dx} = \nu f(x)$$

and denote the differential coefficients with respect to x by dashes, we obtain:—

$$\left.\begin{aligned}
&a_1 \text{ free}, && a_4 = \frac{1}{\nu} a_1 a_1' \text{ therefore free},\\
&a_2 = f, && a_5 = \frac{2}{\nu} a_1 f',\\
&a_3 = 0, && a_6 = \frac{2}{\nu} f f',\\
&a_7 = \frac{1}{\nu^2}\{4 a_1^2 a_1'' - a_1 a_1'^2\} \text{ therefore free},\\
&a_8 = \frac{1}{\nu^2}\{10 a_1^2 f'' - 13 a_1 a_1' f' + 9(a_1 a_1'' + a_1'^2) f\},\\
&a_9 = \frac{1}{\nu^2}\{40 a_1 f f'' - 16 a_1 f'^2\},
\end{aligned}\right\} \quad . \quad . \quad (2.4)$$

whence it can be seen that in order to define a velocity profile at a position $x = x_0$ for a given $f(x)$, only a_1, a_4, a_7, . . . , are available. Fulfilment of these "Bindungen" by $u(x_9, y)$ ensures regular behaviour of the integral in (2.1).

The series (2.3) now provides the means by which expression (2.1) can be extended from the wall. We will first describe its calculation for a given velocity profile at $x = x_0$ and a given pressure distribution.

The initial profile $u(x_0, y)$ will in general no longer exactly satisfy the "Bindungen," so that the calculated series oscillates slightly about the given profile $u(x_0, y)$. We have already investigated (9) by means of an example the problem of how this rectification of a profile at $x = x_0$ affects the subsequent curve for $x > x_0$. Up to the separation point no effects exceeding the error made at $x = x_0$ are to be expected.

In the example to be given we will deal with the series (2.3) up to and including the term containing a_9. In order to determine the a_ν values when one profile $u(x_0, y)$ satisfying the "Bindungen" is given, the following method of successive approximations has proved suitable. In the first place, the given fixed terms a_2, ($a_3 = 0$), a_6 are calculated and the corresponding terms of the series are tabulated against y as far as they are required. For a small ordinate $y = y_1$ (or extrapolation $y_1 > 0$), a first approximation for a_1, and thus also first approximations for a_5 and a_9, are calculated from the deviation of this part of the series from the given profile $u(x_0, y)$. Then, in the same way and by simultaneously using the terms of the series corresponding to a_1, a_5 and a_9 at a suitable ordinate $y = y_2 > y_1$, a first approximation is obtained for the coefficient

a_4, and finally improved values are calculated for a_1, and thus a second approximation is obtained for a_1, a_5, a_9. For a third ordinate $y=y_3>y_2$, first approximations are then determined simultaneously for a_7 and a_8 (perhaps rewritten as an equation for a_1''). This is followed by determination of improved values for a_4 (second approximation) and—so far as is necessary—for a_1, a_5, a_9 (third approximation). The first approximations obtained for coefficients a_7 and a_8 are naturally inaccurate, but they are sufficient to enable an improvement of a_4, and apart from this their only rôle is in obtaining an approximation for the given profile $u(x_0, y)$ up to greater y values.

It is not suitable to definitely fix the ordinates y_1, y_2, y_3; their most suitable positions vary within certain narrow limits from step to step. It is not therefore advisable to take once and for all a system of equations with fixed y_1, y_2, y_3, as a basis for calculating a_ν.

C. In order to apply the series (2.3) in conjunction with the integral expression (2.1), the following points should be noted:—

In the original plan provision was made for deriving the required value $\partial u/\partial x\,(x_0, y)$ independently, once from the series (2.3) and then from a certain y_0 value >0 using the expression (2.1). Then, by suitable choice of the $\phi(x)$ values, both partial solutions had to be made to fit together continuously in the range of overlap. I have departed from this procedure for the following reasons. In the first place $\partial u/\partial x$ is obtained from the series (2.3) as:—

$$\frac{\partial u}{\partial x}=a'_1 y+a'_2\frac{y^2}{2!}+a'_4\frac{y^4}{4!}+\ldots \quad . \quad . \quad . \quad . \quad (2.5)$$

and a'_4, for whose calculation from (2.4) it is necessary to know a''_1 and therefore a_7, is only known as a first approximation (a'_1 as a second approximation, a'_2 given). Since the reliability of the approximation (2.5) does not extend far from the wall, it is possible to obtain a sufficient region of overlap when using the values obtained from (2.1) for the interior of the boundary layer, only if one is prepared to go to the considerable trouble of calculating further terms of the series (2.3) and thus obtaining an improved value of a_7. If this extra work is not undertaken then the determination of $\phi(x)$ will be quite inaccurate. The numerical or graphical integrations necessary for building up the expression (2.1) become unreliable in proximity to the wall; the errors due to division by u^2, which becomes very small in the neighbourhood of the wall, are strongly felt, particularly in the region of separation. Therefore, in the case of y_0 also, it is not possible to go too near to the wall, in order not to introduce too great error into the determination of $\phi(x)$.

On the contrary, the procedure is as follows:—Using the partial series (2.3) for u, we calculate $\partial u/\partial y$ and $\partial^2 u/\partial y^2$ from $y=0$ to as far into the interior of the boundary layer as the validity of the series will permit (10):—

$$\frac{\partial u}{\partial y}=\sum_{\nu=1}^{9} a_\nu\frac{y^{\nu-1}}{(\nu-1)!}; \qquad \frac{\partial^2 u}{\partial y^2}=\sum_{\nu=2}^{9} a_\nu\frac{y^{\nu-2}}{(\nu-2)!}\ ;\ 0\leqq y\leqq y_3) \quad . \quad (2.6)$$

Within this range of applicability the series expressions are substituted directly in (2.1). We rewrite (2.1) in a form suitable for numerical calculation:—

$$\frac{\partial u}{\partial x}=\frac{\partial u}{\partial y}\int_0^y\frac{1}{u^2}\left\{\nu\frac{\partial^2 u}{\partial y^2}-\frac{1}{\rho}\frac{dp}{dx}\right\}dy+\frac{1}{u}\left\{\nu\frac{\partial^2 u}{\partial y^2}-\frac{1}{\rho}\frac{dp}{dx}\right\} \quad . \quad (2.7)$$

The values calculated from (2.3), (2.6) coincide with the numerically or graphically obtained values over a sufficiently wide range of y within the boundary layer to permit a fit to be made with the necessary accuracy. Only after the fit has been carefully made is it divided by the small value of u^2 near to the wall. In addition, an essential advantage is that the integral is now calculated from $y=0$, so that the uncertainty of the $\phi(x)$ determination is completely eliminated ($\phi(x)\equiv 0$!).

D. On the question of the best way of carrying out the step leading from a given velocity profile $u\,(x_0, y)$ to the neighbouring profile $u\,(x_0+\Delta x, y)$, the following remarks may be made. For the range $0 \leqq x \leqq x_0$ the velocity distribution in the boundary layer is known—from any solution which is valid there, say that of Blasius. By means of the method described above $(\partial u/\partial x)_{x_0, y}$ will be calculated at the initial point $x=x_0$ of the continuation process. Imagine $u\,(x, y)$ to be expanded into a power series for a given distance from the wall $y=y_c$ at $x=x_0$:—

$$u\,(x, y_c)=b_0+b_1\,(x-x_0)+b_2\,(x-x_0)^2+b_3\,(x-x_0)^3+\ldots.$$

then, in the ordinary further expansion of $u\,(x_0, y_c)$ with the first term of Taylor's series, we obtain:—

$$u\,(x_0+\Delta x, y_c)=u\,(x_0, y_c)+\frac{\partial u}{\partial x}\,(x_0, y_c)\,.\,\Delta x=b_0+b_1\Delta x,$$

however, using the known quantities and with the same amount of labour, a better approximation can generally be obtained by putting:—

$$\left.\begin{aligned} u\,(x_0+\Delta x, y_c) &= u\,(x_0-\Delta x, y_c)+\frac{\partial u}{\partial x}\,(x_0, y_c)\,.\,2\,\Delta x \\ &= b_0+b_1\,.\,\Delta x+b_2\,.\,\Delta x^2-b_3\,.\,\Delta x^3+\ldots \end{aligned}\right\} \quad . \quad . \quad (2.8)$$

i.e., when the secant shown in Fig. 1 is used in place of the tangent (the shape of the curves $u\,(x, y_c)$ for our example shown in Fig. 6 is taken for this purpose).

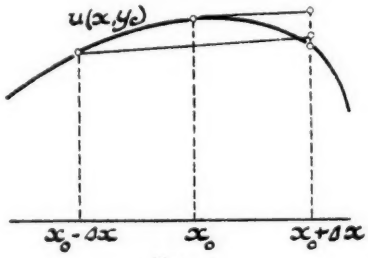


FIG. 1.

The next step is then:—

$$u\,(x_0+2\,\Delta x, y_c)=u\,(x_0, y_c)+\frac{\partial u}{\partial x}\,(x_0+\Delta x, y_c)\,.\,2\,\Delta x$$

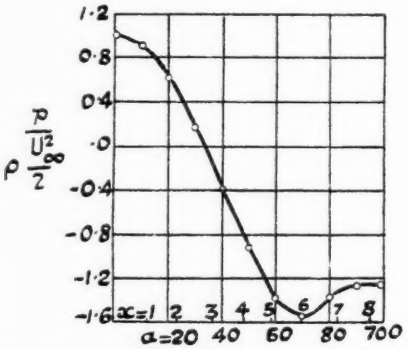
and so on. Obviously the method can be improved if a greater amount of work is undertaken. In the numerical example given later we have confined ourselves to this approximation. According to the accuracy of the initial data and the graphical method used it gives a solution within an accuracy of 1 per cent. when using conveniently large steps. If the permissible error in the continuation method with reference to the appropriate value of u is ϵ, then the size of step is proportional to $\epsilon^{\frac{1}{2}}$, assuming that the error in numerical calculation of $\partial u/\partial x\,.\,2\,\Delta x$ does not itself exceed this error. The latter consideration is the factor determining the size of the step Δx, in our example, in the region of the separation point where $\partial u/\partial x$ increases rapidly.

II. Practical Testing of the Method.

3. Blasius-Hiemenz Solution for a Straight, Circular Cylinder Immersed in a Uniform Flow.

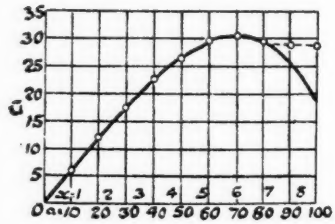
In order to try out the method, the pressure distribution on a circular cylinder, measured by Hiemenz (11), was selected. It is well known that Blasius' solution for this case yields a separation point in good agreement with measurements, although the velocity distribution within the boundary layer is no longer given correctly up to the separation point. Since our method remains valid, even when

Blasius' solution completely breaks down, it is possible by testing it out in this case to provide possibilities of comparison, and to form a general judgment upon the method.



Pressure distribution on a circular cylinder as given by Hiemenz.

FIG. 2.



---o--- ū as given by Hiemenz measurements.

—— ū calculated by equation (3·1)

FIG. 3.

The straight circular cylinder used in Hiemenz measurements had a diameter of $2r=9.75$ cm. and it was immersed in a uniform flow of water ($\nu=0.01$) having an undisturbed velocity of $U_\infty=19.2$ cm./sec. ($Re=U_\infty r/\nu=9360$). On the basis of the measured pressure distribution, shown in Fig. 2, Hiemenz gives the following expression for the velocity distribution $u=\bar{u}(x)$ at the outer edge of the boundary layer:—

$$\bar{u}=u_1x+u_3x^3+u_5x^5 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.1)$$

where $u_1=7.151$; $u_3=-0.04497$; $u_5=-0.0003300$; within the range $0\leqq x\leqq 7$ cm., this gives results agreeing with the measured results within 0.4 per cent. referred to the maximum velocity (see Fig. 3). From this we obtain for the pressure gradient

$$\frac{dp}{dx}=\sum_{\nu=0}^{4} p_{2\nu+1}x^{2\nu+1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.2)$$

where

$$p_1=-51.14;\quad p_3=1.280;\quad p_5=0.008092^{12};\quad p_7=-0.0001187;$$
$$p_9=-0.0000005445.$$

Blasius' solution gives the following expression for the stream function ψ :—

$$\psi = \psi_1 x + \psi_3 x^3 + \psi_5 x^5 + \ldots \quad . \quad . \quad . \quad . \quad . \quad (3.3)$$

where the ψ values are functions of y and thus :—

$$\left.\begin{aligned} u &= \psi'_1 x + \psi'_3 x^3 + \psi'_5 x^5 + \ldots \\ -v &= \psi_1 + 3\,\psi_3 x^2 + 5\,\psi_5 x^4 + \ldots \end{aligned}\right\} . \quad . \quad . \quad . \quad . \quad (3.4)$$

By substituting in (1.1) we arrive at differential equations for the ψ_v values, which by certain transformations can be free from the special data pertaining to the problem (13). The numerical integrations were continued by Howarth (and also extended to the general case of a body which is not symmetrical with respect to the direction of flow). These tables of functions include the first three terms of the series (3.3). In calculating Blasius-Hiemenz solution for a circular cylinder we have taken Howarth's tables (14) as a basis.

4. Introduction of Non-Dimensional Quantities.

For the purpose of easier access to the tables of functions mentioned, and at the same time to introduce non-dimensional quantities, we put :—

$$\left.\begin{aligned} x' &= \frac{x}{l}, \quad y' = \left(\frac{u_0}{\nu l}\right)^{\frac{1}{2}} y, \\ u' &= \frac{u}{u_0}, \quad v' = \left(\frac{l}{\nu u_0}\right)^{\frac{1}{2}} v, \\ p' &= \frac{p}{\rho u_0^{\,2}} \end{aligned}\right\} . \quad . \quad . \quad . \quad . \quad (4.1)$$

where $l = 1$ cm., $u_0 = u_1 = 7.151$ cm./sec. The differential equation (1.1) then becomes :—

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{dp}{dx} = \frac{\partial^2 u}{\partial y^2} \quad . \quad . \quad . \quad . \quad (4.2)$$

again omitting the strokes. If these non-dimensional quantities are again used to constitute a series of the form

$$u = \Sigma a_\lambda (x)\frac{y^\lambda}{\lambda!}$$

then the coefficient " Bindungen " can be obtained from the equations given in (2.4), by omitting the quantity ν throughout in (2.4) and identifying $f(x)$ with dp/dx.

5. Range of Validity of Blasius-Hiemenz Solution.

In order to test the x values up to which Blasius-Hiemenz solution can be taken as the initial solution, a rough estimate can be made of the error involved by breaking off the series (3.3) after the third term; however, to do this it is necessary to make assumptions with regard to the higher terms which have not been calculated so far. A reliable indication is obtained by investigating the extent to which the Blasius-Hiemenz approximate solution satisfies the " Bindungen " (2.4); for this purpose, the first and most important " Bindung " :

$$\left.\frac{\partial^2 u}{\partial y^2}\right|_{y=0} = \frac{dp}{dx}$$

is the easiest to test. $\partial u/\partial y$ can be calculated directly from Howarth's tables, from which $\partial^2 u/\partial y^2|_{y=0}$ can be deduced with sufficient accuracy. The result of this test is plotted in Fig. 4. From this it can be seen that good agreement exists up to about $x = 4.5$ and that from here onwards this " Bindung " is destroyed to a rapidly increasing extent. In accordance with the accuracy requirement for our further numerical and graphical methods, by which we intend to keep the maximum error involved in one step below 1 per cent. of the corresponding external velocity $\bar{u}(x)$, we take the Blasius-Hiemenz solution as

the initial solution in the range $0 \leqq x \leqq 4.5$. This corresponds to an angular range of about $0 \leqq \alpha \leqq 55°$ measured from the radius towards the front stagnation point. The pressure minimum is at $\alpha = 71°$ (see Fig. 2) and separation was observed shortly before $x = 7$ ($\alpha = 80°$ to $82°$).

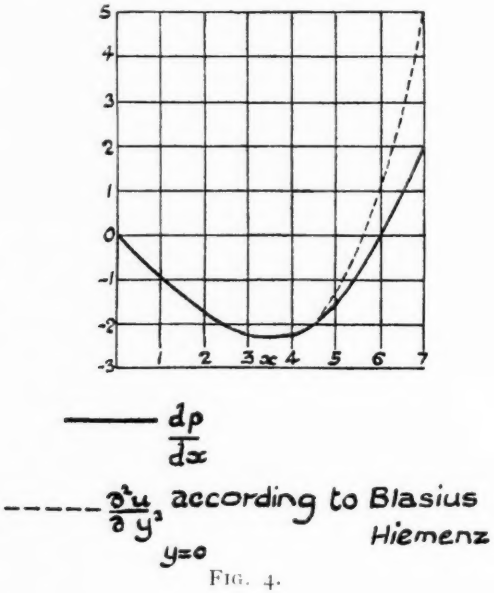


FIG. 4.

6. THE SIZE OF STEP.

In approximating to $u(x, y)$ by means of the related series $\Sigma a_\nu (y^\nu/\nu!)$ up to and including the term $(a_9/9!)\, y^9$, we obtained agreement in the range from $y = 0$ up to values between 1.6 and 2.4, the permissible deviation of the series being a maximum of 0.5 per cent. referred to the corresponding $\bar{u}(x)$ value. This accuracy was necessary in order to obtain $\partial u/\partial y$ and $\partial^2 u/\partial y^2$ with sufficient approximation; these are calculated from the series up to an average $y = 1.4$.

Within the boundary layer $\partial u/\partial y$ was obtained by careful graphical differentiation (15), and the values obtained were joined up to the values calculated from the series starting from the wall. The variation in $\partial^2 u/\partial y^2$ was then determined by the same method. The integration necessary for forming $\partial u/\partial x$ was performed graphically.

The following step was carried out in an endeavour to keep the error below 1 per cent. (16):—

$$(u)_{x_\nu} + 2\,\Delta x \left(\frac{\partial u}{\partial x}\right)_{x_{\nu+1}} = (u)_{x_{\nu+2}}$$

x_ν	$x_{\nu+1}$	$x_{\nu+2}$	Δx	$\Delta\alpha°$
4	4·5	5	0.5	5.88
4·5	5	5·5	0.5	5.88
5·25	5·5	5·75	0.25	2.94
5·5	5·75	6	0.25	2.94
5·75	6	6.25	0.25	2.94
6	6.25	6.5	0.25	2.94
6.35	6.5	6.65	0.15	1.76
6.55	6.65	6.75	0.1	1.18

With each reduction in the size of step an additional new profile had to be calculated (at $x=5.25$; 6.35; 6.55). This was done without much trouble by continuing the appropriate Blasius-Hiemenz profile, lying at a given value of $x < 4.5$, from that point up to the required position by means of the already calculated $\partial u/\partial x$ tables; thus, for example, in order to calculate $u|_{x=5.25}$:—

$$(u)_{x=4.25} + \tfrac{1}{2}\left(\frac{\partial u}{\partial x}\right)_{x=4.5} + \tfrac{1}{2}\left(\frac{\partial u}{\partial x}\right)_{x=5} = (u)_{x=5.25}$$

At first the size of step was determined only by the error involved in the continuation method, which has already been discussed in Section 2 D. Naturally it is advisable to estimate this in advance, and the subsequent control has to strictly test whether the set limit of error has been adhered to. By graphical differentiation of the calculated u curve we have confirmed that the maximum permissible error of 1 per cent. with respect to $\bar{u}$ was never reached and, almost throughout, it was far from this value. The extraordinarily sharp increase of $\partial u/\partial x$ caused by the very sudden increase in pressure on the circular cylinder behind $x=6$ was responsible for the two last reductions in increment and the breaking off of the method; consequently the error present in the $\partial u/\partial x$ values calculated by the graphical and numerical methods becomes felt more, and further steps cannot be followed up by the graphical and numerical auxiliary methods within the set limits of error. With an error of at most 2 per cent. with respect to $\bar{u}$ it is still possible to get to $x=6.8$ ($x_\nu = 6.5$; $x_{\nu+1}=6.65$); however, this degree of accuracy can also be reached by extrapolation. Separation takes place at $x=6.80$ ($\alpha=80°$).

7. Results of Calculation.

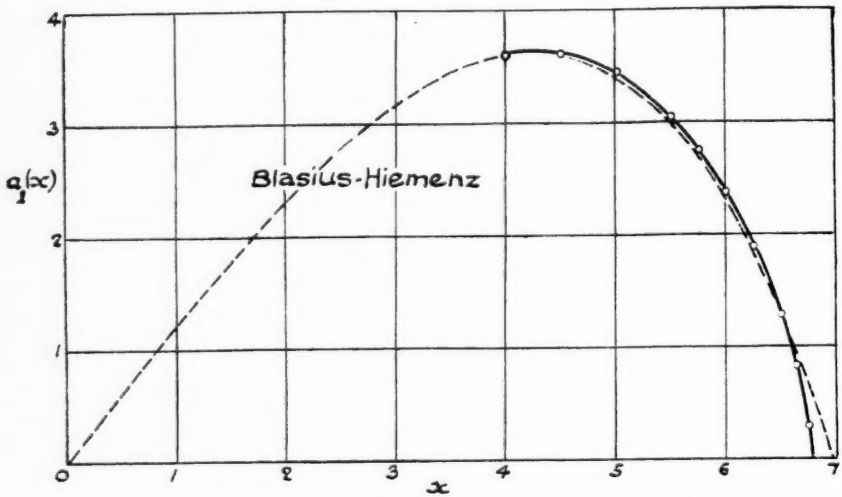
Fig. 5 and Table I give the curve and values of the function

$$a_1(x)=\left(\frac{\partial u}{\partial y}\right)_{y=0}:$$

the dotted curve represents the distribution obtained on the basis of the Blasius-Hiemenz approximate solution; the heavy curve is the function determined by us by step-wise procedure from $x=4.5$ onwards; from that point onwards the curves only digress slowly from one another, a confirmation of the fact that Blasius-Hiemenz approximate solution is still sufficient to give the boundary layer " Bindungen " at $x=4.5$ with good approximation (see Section 5).

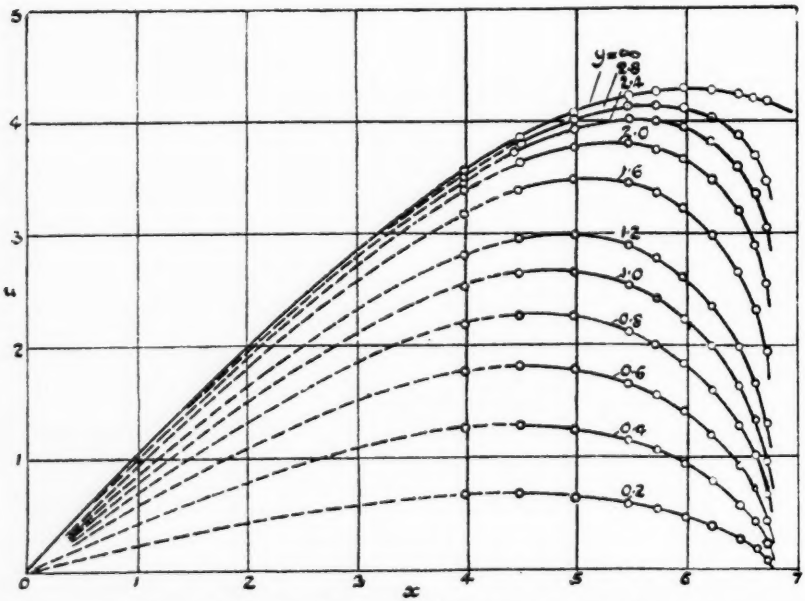
Since in Fig. 5 the two curves overlap, hence the separation point calculated by Hiemenz ($x=6.977$; $\alpha=82°$) differs only slightly from the result of the present calculations ($x=6.80$; $\alpha=80°$). Separation was observed to occur between 80 and 82°.

It should still be noted that when $x \to x_A$, $\partial^3 u/\partial x^3$ has a large negative value and that therefore the approximation (2.8) for u would be expected to be too large, and therefore separation will take place earlier rather than later within the limits of accuracy. However, this only applies if Hiemenz polynomial (3.1) for $u(x)$ is assumed to be valid up to $x=x_A$. Actually the observed curve for $\bar{u}(x)$ becomes horizontal from a turning point lying in front of $x=6.8$, but the polynomial tends towards zero, with opposite curvature (see Fig. 3). The same thing applies to the pressure distribution, and therefore even before $x=x_A$ the value of dp/dx and of the higher differential coefficients, already differ from Hiemenz polynomial and dp/dx will be put smaller. Separation will therefore be expected to occur later than given by Hiemenz polynomial. However, a more accurate investigation shows that the mentioned variation between the observed pressure distribution and that taken as a basis for calculation produces no error affecting the accuracy of our calculations; the error remains of the same order of magnitude as the systematic error previously mentioned, but in the opposite direction. Therefore, up to the separation point, we can be satisfied with the Hiemenz polynomial.



Curve of the Function $a_1(x)$.

FIG. 5.



u(x,y) for various distances y from the wall.

FIG. 6.

In Fig. 6 the curves for $u\,(x, y_e)$ are plotted for various distances y_e from the wall (dotted curves are for Blasius-Hiemenz solution; the continuations calculated by us are shown as heavy curves).

The plotted points characterise the size of step; the intermediate points calculated with reduced increments are not shown (see Section 6).

In order to give a survey of the variation in velocity profile with increasing x, Fig. 7 shows a few of the profiles, calculated and referred to the corresponding

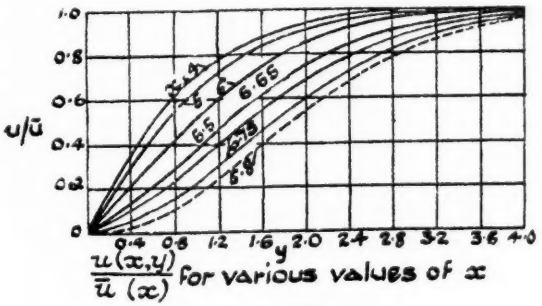


FIG. 7.

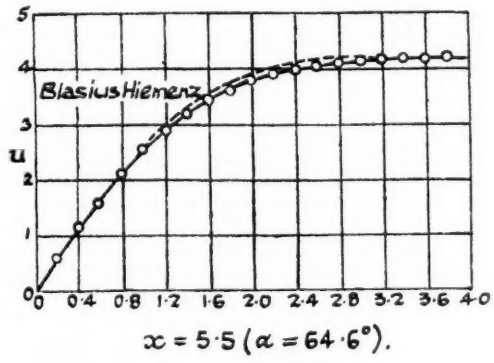


FIG. 8*a*.

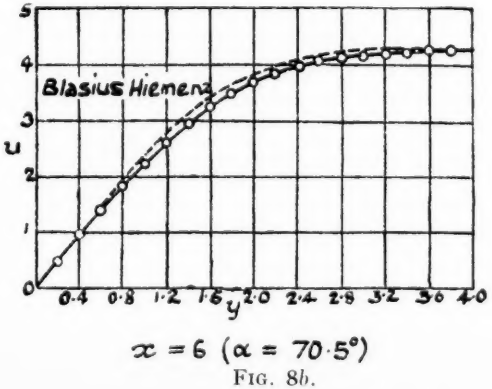
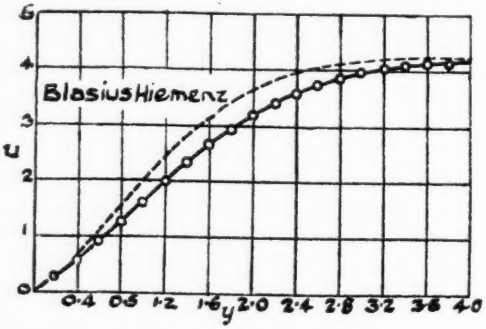


FIG. 8*b*.

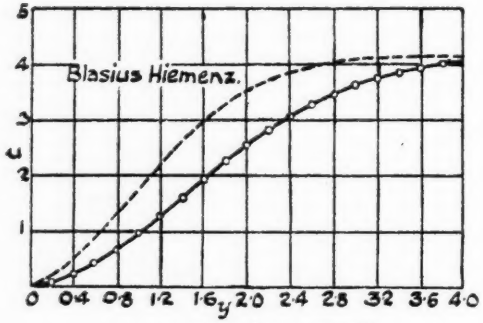
profile $\bar{u}(x)$. The profile at the separation point $x=6.8$ was obtained by extrapolation.

Figs. 8 *a-d* show a few profiles compared with those of the Blasius-Hiemenz approximation. It should be noted that Howarth has carried out a comparison between the well-known v. Kármán-Pohlhausen approximation and the Blasius-Hiemenz profiles; the profiles calculated by us are situated between these two, from which it is evident that the v. Kármán-Pohlhausen approximation gives the velocity distribution in the boundary layer better than was previously assumed.



$x = 5{\cdot}5\ (\alpha = 76{\cdot}4°)$.

FIG. 8*c*.



$x = 6{\cdot}75\ (\alpha = 79{\cdot}3°)$.

FIG. 8*d*.

The method for continuing a boundary layer profile for a given pressure distribution, which has been tested out by means of the present numerical results, gives the separation point and the velocity distribution within the boundary layer with satisfactory accuracy if increments of suitable size are used, and it can therefore be described as suitable for application when Blasius' solution breaks down. As already stressed, the method can be greatly improved, with corresponding increase of work entailed; in the present case the accuracy obtained by the graphical methods, which is generally sufficient, does not justify an increase in labour by refining the continuation method.

Each step took about 10 hours; this expenditure of time was mainly due to the troublesome determination of the series coefficients a_ν. In the case of flows with more gradual pressure gradient than that in the example taken, the method permits the flow to be followed beyond the separation point, so far as this can be reconciled with the factors neglected in the boundary layer theory.

I must not omit to thank my chief, Professor L. Prandtl, for his suggestions regarding this work.

SUMMARY.

A method, the fundamentals of which were suggested in a paper by Prandtl, for continuing a given boundary layer profile when the pressure distribution is given, is worked out in detail and tested in practice in the case of the pressure distribution around a straight circular cylinder immersed in a uniform flow, as measured by Hiemenz. The method proves to be very suitable, although still troublesome, and the boundary layer can be calculated with considerable accuracy up to the separation point.

APPENDIX.

In the following we will show how to calculate one step in the method, namely, at the position $x=6$, selected at random.

1. From equation (3.2) we obtain

$$\frac{dp}{dx} = -0.09497, \quad \frac{d^2p}{dx^2} = 1.822, \quad \frac{d^3p}{dx^3} = 0.6162,$$

and the method of successive approximations described in section 2 B gives:—

$a_1 = 2.395$ (III); $\quad \frac{a_4}{4!} = -0.1720$ (II); $\quad \frac{a_7}{7!} = -0.005371$ (I);

$\frac{a_2}{2!} = -0.04748$ (fixed); $\quad \frac{a_5}{5!} = -0.07274$ (III); $\quad \frac{a_8}{8!} = 0.003283$ (I);

$\frac{a_3}{3!} = 0$ (fixed); $\quad \frac{a_6}{6!} = -0.004807$ (fixed); $\quad \frac{a_9}{9!} = -0.0003661$ (III).

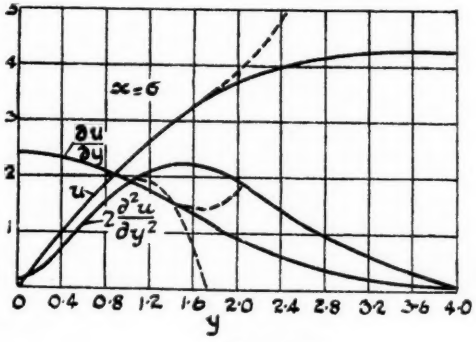


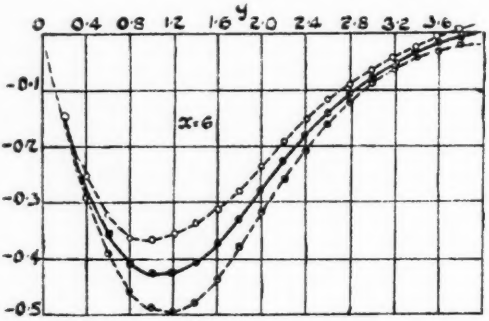
FIG. 9.

The numbers in brackets show which approximation is referred to. Using these values a good approximation was obtained for the velocity profile u (6, y) resulting from the preceding steps, up to $y=1.6$. (Maximum deviation 0.26 per cent. with respect to $\bar{u}$ (6).) The first column of Table III gives the specified velocity distribution u (6, y); the second column gives the approximation obtained by means of the series. In addition to u (6, y), Fig. 9 shows the approximation as a dotted curve.

2. For the third and fourth columns the series alone was used from $y=0$ to $y=1$, and subsequent to that the values were obtained by graphical differentiation from the best estimate; these already agreed well with the calculated values long before $y=1$. In connection with the sixth column we have to note that

$$\frac{1}{u^2}\left\{\frac{\partial^2 u}{\partial y^2} - \frac{dp}{dx}\right\}\Big|_{y=0} = \frac{a_4}{2\,a_1^2}$$

3. $u|_{x=6\cdot25}$ was calculated from $\partial u/\partial x|_{x=6}$ (see Table IV). With regard to the permissible error in calculation, it is noted that an accuracy of 1 per cent. in the $u|_{x=6\cdot25}$ value with respect to $\bar{u}$ (6.25) would necessitate an accuracy of only 10 per cent. in the value of $\partial u/\partial x|_{x=6}$ with respect to its maximum value, an accuracy which is far exceeded. In addition, there is the systematic error in the continuation method, which in this case is again small (it was subsequently determined as, at most, 0.2 per cent. with respect to $\bar{u}$ (6.25), and during the calculation it can only be roughly estimated). Although in this step (with $\Delta x=0.25$) the error remains small, already after one more step of the same length the value of Δx has to be reduced, since $\partial u/\partial x$ increases very quickly behind the pressure minimum. Since for each alteration in the length of increment an additional velocity profile has to be calculated (see Section 6), it is best to select sizes of increment which can be retained for several steps.



$$\circ\ \frac{1}{u}\left\{\frac{\partial^2 u}{\partial y^2}-\frac{dp}{dx}\right\}$$

$$\circ\ \frac{\partial u}{\partial y}\int_0^y \frac{1}{u^2}\left\{\frac{\partial^2 u}{\partial y^2}-\frac{dp}{dx}\right\}dy$$

$$\bullet\ \frac{1}{2}\quad\frac{\partial u}{\partial x}$$

FIG. 10.

TABLE I.

Variation in the function $a_1(x)$ and comparison with the Blasius-Hiemenz values.

x	$a_1(x)$ after B.—H.	x	$a_1(x)$	$a_1(x)$ after B.—H.
0	0	4·5	3·63	3.61
0.5	0.61	5	3·46	3·42
1	1.21	5·5	3·05	3.00
1·5	1.79	5·75	2.76	2.69
2	2.31	6	2.40	2.31
2·5	2.78	6.25	1.90	1.84
3	3·17	6.5	1.28	1.29
3·5	3·45	6.65	0.85	0.91
4	3.61	6.75	0.30	0.64

TABLE II.

Calculated velocity distribution $u\ (x, y)$.

y \ x	4·5	5	5·5	5·75	6	6·25	6·5	6·65	6·75	6·8
0	0	0	0	0	0	0	0	0	0	0
0·2	0·68	0·66	0·59	0·54	0·47	0·39	0·27	0·19	0·08	0·02
0·4	1·29	1·25	1·14	1·06	0·94	0·79	0·58	0·43	0·23	0·09
0·6	1·82	1·79	1·65	1·55	1·41	1·20	0·92	0·71	0·43	0·24
0·8	2·27	2·25	2·12	2·00	1·84	1·59	1·27	1·02	0·68	0·45
1·0	2·65	2·65	2·54	2·41	2·24	1·98	1·62	1·34	0·96	0·71
1·2	2·95	2·97	2·90	2·77	2·60	2·34	1·98	1·65	1·27	1·02
1·4	3·19	3·24	3·20	3·08	2·94	2·67	2·34	1·99	1·61	1·34
1·6	3·38	3·47	3·46	3·35	3·24	2·97	2·66	2·31	1·94	1·66
1·8	3·52	3·63	3·65	3·56	3·47	3·23	2·94	2·61	2·25	1·98
2·0	3·63	3·76	3·81	3·74	3·67	3·46	3·19	2·89	2·54	2·28
2·2	3·71	3·86	3·94	3·89	3·83	3·66	3·41	3·14	2·82	2·56
2·4	3·75	3·92	4·02	3·99	3·95	3·81	3·59	3·35	3·05	2·83
2·6	3·78	3·97	4·09	4·07	4·04	3·93	3·74	3·53	3·27	3·06
2·8	3·81	4·01	4·14	4·14	4·12	4·03	3·87	3·69	3·46	3·28
3·0	3·83	4·04	4·17	4·18	4·17	4·10	3·97	3·81	3·62	3·47
3·2	3·83	4·05	4·19	4·21	4·21	4·15	4·04	3·91	3·75	3·62
3·4	3·84	4·06	4·20	4·23	4·23	4·19	4·10	3·99	3·85	3·74
3·6	3·84	4·07	4·21	4·24	4·25	4·22	4·14	4·05	3·93	3·84
3·8	3·84	4·07	4·21	4·25	4·26	4·24	4·17	4·09	4·00	3·93
∞	3·84	4·07	4·22	4·26	4·28	4·27	4·24	4·20	4·17	4·15

TABLE III.

Calculation of $\partial u/\partial x|_{x=6}$.

y	u	$u=\sum_{\nu=1}^{9}\frac{a_\nu y^\nu}{\nu!}$	$\frac{\partial u}{\partial y}$	$\frac{\partial^2 u}{\partial y^2}-\frac{dp}{dx}$	$\frac{1}{u}\left(\frac{\partial^2 u}{\partial y^2}-\frac{dp}{dx}\right)$	$\frac{\partial u}{\partial y}\int_0^y\frac{1}{u^2}\left(\frac{\partial^2 u}{\partial y^2}-\frac{dp}{dx}\right)dy$	$\frac{\partial u}{\partial x}$
0	0	0	2·395	0	0	0	0
0·2	0·471	0·477	2·371	−0·071	−0·149	−0·160	−0·309
0·4	0·943	0·947	2·322	−0·242	−0·256	−0·292	−0·548
0·6	1·408	1·403	2·233	−0·457	−0·326	−0·393	−0·719
0·8	1·839	1·837	2·101	−0·666	−0·362	−0·460	−0·822
1·0	2·237	2·241	1·932	−0·822	−0·367	−0·492	−0·859
1·2	2·601	2·612	1·752	−0·927	−0·356	−0·499	−0·855
1·4	2·943	2·938	1·552	−0·996	−0·338	−0·481	−0·819
1·6	3·237	3·237	1·335	−1·022	−0·316	−0·442	−0·758
1·8	3·473	3·523	1·104	−0·991	−0·285	−0·384	−0·669
2·0	3·670	—	0·888	−0·887	−0·242	−0·322	−0·564
2·2	3·833	—	0·699	−0·744	−0·194	−0·261	−0·455
2·4	3·949	—	0·547	−0·600	−0·154	−0·209	−0·363
2·6	4·043	—	0·421	−0·489	−0·121	−0·164	−0·285
2·8	4·121	—	0·313	−0·383	−0·093	−0·124	−0·217
3·0	4·171	—	0·222	−0·285	−0·068	−0·080	−0·157
3·2	4·206	—	0·156	−0·198	−0·047	−0·063	−0·110
3·4	4·229	—	0·108	−0·115	−0·027	−0·044	−0·071
3·6	4·247	—	0·076	−0·040	−0·009	−0·031	−0·040
3·8	4·259	—	0·052	+0·023	+0·005	−0·021	−0·016
∞	4·283	—	0·000	0·095	0·022	0·000	+0·022

TABLE IV.

Calculation of $u|_{x=6\cdot25}$.

y	$u\|_{x=5.75}$	$\frac{1}{2}\frac{\partial u}{\partial x}\|_{x=6}$	$u\|_{x=6.25}$
0	0	0	0
0.2	0.540	−0.155	0.385
0.4	1.061	−0.274	0.787
0.6	1.555	−0.359	1.196
0.8	2.004	−0.411	1.593
1.0	2.413	−0.430	1.983
1.2	2.770	−0.4288	2.342
1.4	3.084	−0.410	2.674
1.6	3.350	−0.379	2.971
1.8	3.564	−0.334	3.230
2.0	3.744	−0.282	3.462
2.2	3.890	−0.228	3.662
2.4	3.993	−0.182	3.811
2.6	4.075	−0.142	3.933
2.8	4.138	−0.108	4.030
3.0	4.181	−0.078	4.103
3.2	4.209	−0.055	4.154
3.4	4.229	−0.036	4.193
3.6	4.242	−0.020	4.222
3.8	4.252	−0.008	4.244
∞	4.264	+0.011	4.275

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6. L. Prandtl. See reference 1, p. 78, equation (4).
7. L. Prandtl. See reference 1, p. 78.
8. L. Prandtl. See reference 1, p. 78, and in particular p. 82.
9. L. Prandtl. See reference 1, pp. 80-81.
10. It can easily be confirmed that the calculated expressions are valid over a region extending farther inside the boundary layer than is the case for (2.5). From the point of view of accuracy of the approximation obtained (2.5) is equivalent to a three-fold differentiation with respect to y, on the basis of the "Bindungen."
11. K. Hiemenz. See reference 4.
12. Given by Hiemenz (see reference 4) with a pressure error.
13. As first generally recognised by Howarth. See reference 5, p. 7 onwards.
14. L. Howarth. Loc. cit., pp. 51-52.
15. According to C. Runge (Graphical Methods, Leipzig and Berlin 1915, p. 112) graphical differentiation by repeatedly halving the chord will give more reliable results after a certain amount of practice than is generally assumed. Moreover this method has already been given by Lambert, see "Applications of Mathematics II," Berlin 1770.
16. As in all methods of step-by-step procedure the errors made at each step can naturally add up.

THE BENT STRUT WITH VARIABLE CROSS SECTION.

By Jean Drymael,

Assistant Professor in the University of Brussels.

Summary.

A graphical method is developed for solving the problem of the beam with variable section, bent by transverse loads and an axial load. The latter may be either tensile or compressive. The beam on statically determinate supports is first dealt with, successively as regards the stress and the deformation. Then a similar procedure is followed for a beam with redundant supports. Finally, the case is studied when there is no transverse load at all, that is buckling only.

Chapter I.

Properties of the M Curve.

1. Conventions.

The *x axis* coincides with the axis of the beam before deformation, and is directed towards the right; the z axis is directed upwards (Fig. 1).

The *transverse loads* are considered positive when acting upwards, and the *external moments* positive when acting in a clockwise direction.

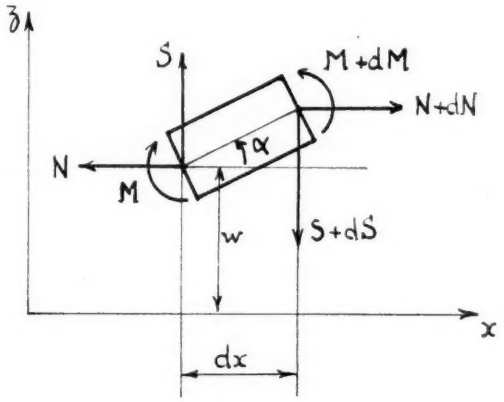

Fig. 1.

The *shear* S and the *axial force* N on a section are the projections of the total force on the z and x axes, and not on the axes bound to the section itself. The shear is positive when the left part tends to move upwards against the right one, and the axial force N is positive when there is traction.

The *bending moment* M is positive when the left part tends to move in a clockwise sense, or when the concavity of the elastic line is upwards.

The *slope* α of the elastic line is positive when the deflection increases towards the right, the *deflection* w being positive when directed upwards.

2. Equations of Equilibrium.

It will be supposed first that only distributed loads p are applied on the beam. The equilibrium of an element of length dx is expressed by:—

$$dN = 0 \quad \text{or} \quad N = \text{const.}$$

$$dS = p\,dx \quad \text{or} \quad S' = p \qquad (1)$$

$$dM = S\,dx + N\,dw \quad \text{or} \quad M' = S + N\alpha \qquad (2)$$

since

$$\alpha = \frac{dw}{dx} \qquad (3)$$

The axial force N is thus constant between two adjacent supports.*

Deriving Eq. 2 one gets:—

$$M'' - Nw'' = p \qquad (4)$$

Since

$$w'' = \alpha' = \frac{M}{EI} \qquad (5)$$

the bending moments must satisfy the well known equation

$$M'' - \frac{M}{\lambda^2} = p \qquad (6)$$

with

$$\lambda^2 = \frac{EI}{N} \qquad (7)$$

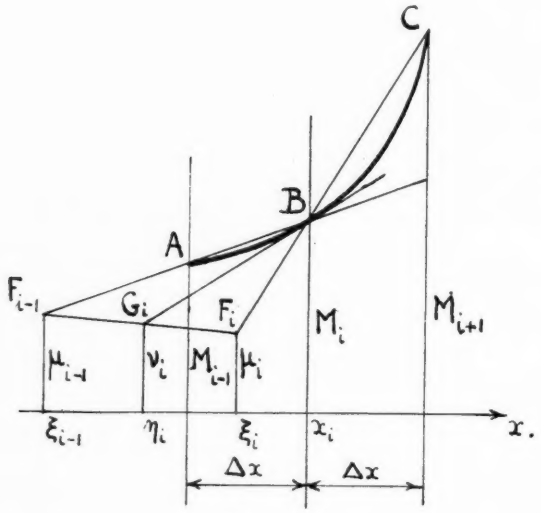

Fig. 2.

The length λ is real if there is tension and imaginary if there is compression.

Howard's solution† of Eq. 6 is particularly elegant in the case of compression when λ is constant. But it becomes rather intricate when λ varies along the length and is not applicable in the case of tension.

* It must be noticed that the projections of the total force on the axes bound to the section are $S + N\alpha = M'$ and $N - S\alpha$. The latter is thus not constant.

† The Stresses in Aeroplane Structures. H. B. Howard.

Let an element of the beam be studied that is sufficiently short to allow p and λ to be considered as constants, in the neighbourhood of the abscissa x_i. The general solution of Eq. 6 is

$$M = -p_i\lambda_i^2 + (A+B)\,e^{\frac{x-xi}{\lambda i}} + (A-B)\,e^{-\frac{x-xi}{\lambda i}}$$

Let the exponentials be replaced by their expansions in series

$$M = -p_i\lambda_i^2 + 2A + 2B\frac{x-x_i}{\lambda_i} + \frac{2A}{2}\left(\frac{x-x_i}{\lambda_i}\right)^{2*} + \ldots \quad . \quad . \quad . \quad (8)$$

The parabolic approximation is sufficiently accurate for practical purposes if $x-x_i/|\lambda_i|$ is smaller than $1/2$. The beam will thus be divided in equal intervals the length Δx of which is sufficiently small against the smallest value of $|\lambda|$; let M_{i-1}, M_i, M_{i+1} be the values of M corresponding to the abscissæ $x_i-\Delta x$, x_i, $x_i+\Delta x$ (Fig. 2).

The equation of M in the interval is

$$M = M_i + (M_{i+1} - M_{i-1})\frac{x-x_i}{2\,\Delta x} + (M_{i-1} - 2\,M_i + M_{i+1})\frac{(x-x_i)^2}{2\,\overline{\Delta x}^2} \quad . \quad (9)$$

Identifying expressions (8) and (9) of M:—

$$2A = M_i + p_i\lambda_i^2 = (M_{i+1} - 2\,M_i + M_{i-1})\left(\frac{\lambda_i}{\Delta x}\right)^2$$

Whence

$$M_{i+1} - M_{i-1} = p_i\Delta x^2 + M_i\left(\frac{\Delta x}{\lambda_i}\right)^2 + 2\,(M_i - M_{i-1}) \quad . \quad . \quad (10)$$

and

$$M = M_i + \frac{x-x_i}{2\,\Delta x}\left[p_i\overline{\Delta x}^2 + M_i\left(\frac{\Delta x}{\lambda_i}\right)^2 + 2\,(M_i - M_{i-1})\right] + \frac{(x-x_i)^2}{2\,\lambda_i^2}\left[M_i + p_i\lambda_i^2\right] \quad (11)$$

3. Properties of the Chords of the M Curve.

If the chord AB of the left interval passes through a fixed point F_{i-1} the chord BC of the second interval passes through another fixed point F_i (Fig. 2).

Let ξ_{i-1} and μ_{i-1} be the co-ordinates of F_{i-1}. The ordinates of A and B equal

$$\left.\begin{aligned} M_{i-1} &= \mu_{i-1} + n\,(x_i - \Delta x - \xi_{i-1}) \\ M_i &= \mu_{i-1} + n\,(x_i - \xi_{i-1}) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (12)$$

The equation of chord BC is, remembering Eq. 10,

$$M = M_i + (M_{i+1} - M_i)\frac{x-x_i}{\Delta x} = M_i + \frac{x-x_i}{\Delta x}\left[p_i\overline{\Delta x}^2 + M_i\left(\frac{\Delta x}{\lambda_i}\right)^2 + M_i - M_{i-1}\right]$$

Or, introducing (12),

$$M = \mu_{i-1} + \frac{x-x_i}{\Delta x}\left[p_i\overline{\Delta x}^2 + \mu_{i-1}\left(\frac{\Delta x}{\lambda_i}\right)^2\right]$$

$$+ n\left[x_i - \xi_{i-1} + \frac{x-x_i}{\Delta x}\left\{(x_i - \xi_{i-1})\left(\frac{\Delta x}{\lambda_i}\right)^2 + \Delta x\right\}\right] \quad . \quad . \quad (13)$$

The ordinate is independent of n if x takes the value ξ_i defined by

$$x_i - \xi_i = \frac{+(x_i - \xi_{i-1})\,\Delta x}{\Delta x + (x_i - \xi_{i-1})\,(\Delta x/\lambda_i)^2} \quad . \quad . \quad . \quad . \quad (14)$$

and for that abscissa it equals

$$\mu_i = \mu_{i-1} + \frac{(\xi_i - x_i)\,\Delta x}{\lambda_i^2}\left[p_i\lambda_i^2 + \mu_{i-1}\right] = \mu_{i-1} + \frac{\xi_i - \xi_{i-1}}{x_i - \xi_{i-1}}\left(-p_i\lambda_i^2 - \mu_{i-1}\right) . \quad (15)$$

It is easily seen that the abscissa ξ_i is given by the graphical construction of Fig. 3. MN represents unity and NP equals $(\Delta x/\lambda_i)^2$; the point on the x axis of abscissa ξ_{i-1} is joined to N and the length NP is measured at QR. The intersection of RN with the x axis gives ξ_i. This part of the construction is

independent of the transverse load. Its accuracy is easily improved by drawing a triangle $NQ'R'$ twice, three times, etc., larger than NQR. The ordinate μ_i is found by drawing in MD a length equalling $-p_i\lambda_i^2$. The fixed point F_i lies on the straight line $F_{i-1}D$.

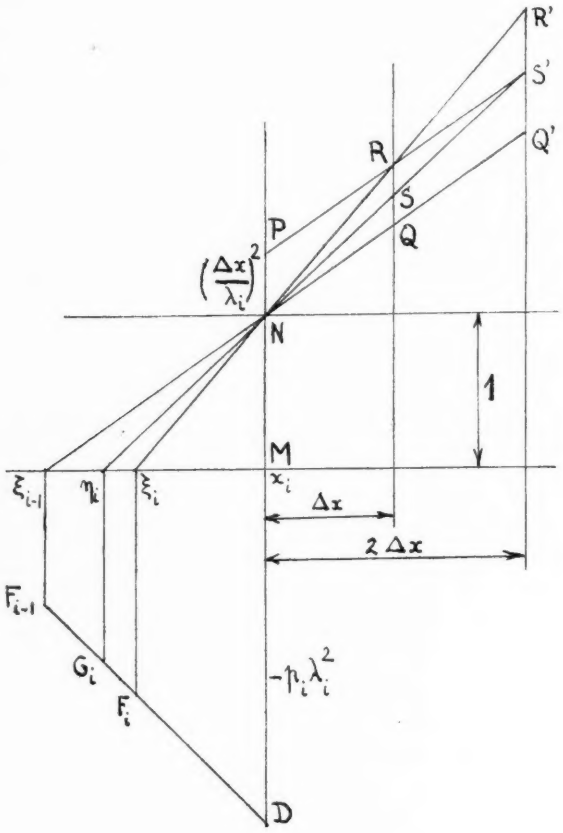

FIG. 3.

4. PROPERTIES OF THE TANGENTS TO THE M CURVE.

If the chord AB of the first interval passes through a fixed point F_{i-1} the tangent to the curve in B passes through another fixed point G_i (Fig. 2).

The equation of the tangent in B is obtained by dropping the last term in Eq. 11. If expressions (12) are used the equation of the tangent becomes

$$M=\mu_{i-1}+\frac{x-x_i}{2\,\Delta x}\left[p_i\overline{\Delta x}^2+\mu_{i-1}\left(\frac{\Delta x}{\lambda_i}\right)^2\right]$$
$$+n\left[x_i-\xi_{i-1}+\frac{x-x_i}{2\,\Delta x}\left\{(x_i-\xi_{i-1})\left(\frac{\Delta x}{\lambda_i}\right)^2+2\,\Delta x\right\}\right]$$

The ordinate is independent of n if x takes the value η_i defined by

$$x_i-\eta_i=\frac{2\,(x_i-\xi_{i-1})\,\Delta x}{2\,\Delta x+(x_i-\xi_{i-1})\,(\Delta x/\lambda_i)^2} \quad . \quad . \quad . \quad . \quad (16)$$

and for that abscissa it equals

$$v_i = \mu_{i-1} + \frac{(\eta_i - x_i)\,\Delta x}{2\,\lambda_i^2}\,[\,p_i\lambda_i^2 + \mu_{i-1}\,] = \mu_{i-1} + \frac{\eta_i - \xi_{i-1}}{x_i - \xi_{i-1}}\,[\,-p_i\lambda_i^2 - \mu_{i-1}\,] \quad . \qquad (17)$$

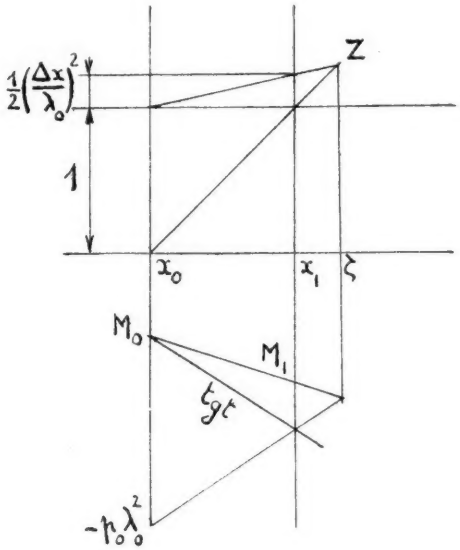

FIG. 4.

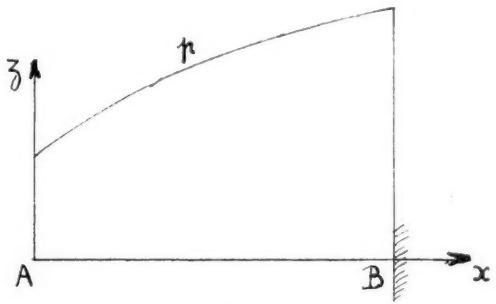

FIG. 5.

To find η_i the same construction is used as for ξ_i except that QS is half of QR (or $Q'S'$ one half of $Q'R'$); G_i lies on $F_{i-1}D$ as F_i.

As soon as the ordinates of the M curve are known all tangents are thus determined except the initial one.

It follows from (Eq. 10) that

$$M_{i+1} - M_{i-1} = -p_i\Delta x^2 - M_i\left(\frac{\Delta x}{\lambda_i}\right)^2 - 2\,(M_i - M_{i-1}).$$

This expression represents (*cf.* Eq. 9) the slope of the tangent multiplied by $2\,\Delta x$. Applying that relation to the initial point

$$2\,\Delta x\left(\frac{dM}{dx}\right)_0 = \frac{\overline{\Delta x}^2}{\lambda_0^2}(-p_0\lambda_0^2 - M_0) + 2\,(M_1 - M_0).$$

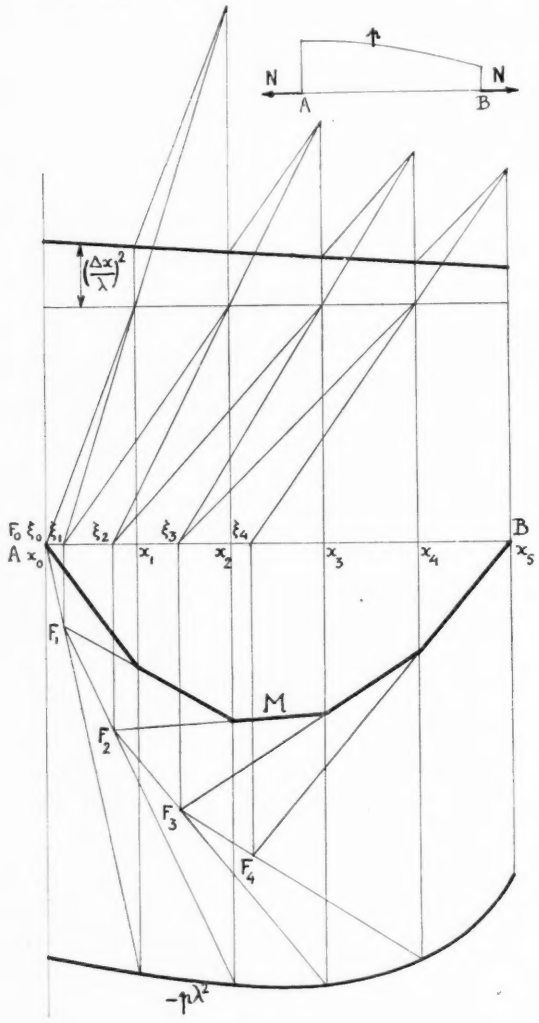

FIG. 6.

The length that must be added to the ordinate M_1 to find the intersection of the initial tangent with its vertical is thus

$$\Delta x\left(\frac{dM}{dx}\right)_0 - (M_1 - M_0) = \frac{\overline{\Delta x}^2}{2\,\lambda_0^2}(-p_0\lambda_0^2 - M_0).$$

It is graphically determined as shown by Fig. 4. The abscissa of point Z will be called ζ.

Chapter II.

The Beam on Statically Determinate Supports.

5. Boundary Conditions.

Since Eq. 6 is of the second order two boundary conditions are required. If the supports are statically determinate those conditions are easily found by considering the ends of the beam. Each of them may be free, pin-jointed or built-in.

If the end is free or pin-jointed the bending moment is zero. The conditions are thus known at once if both ends are pin-jointed.

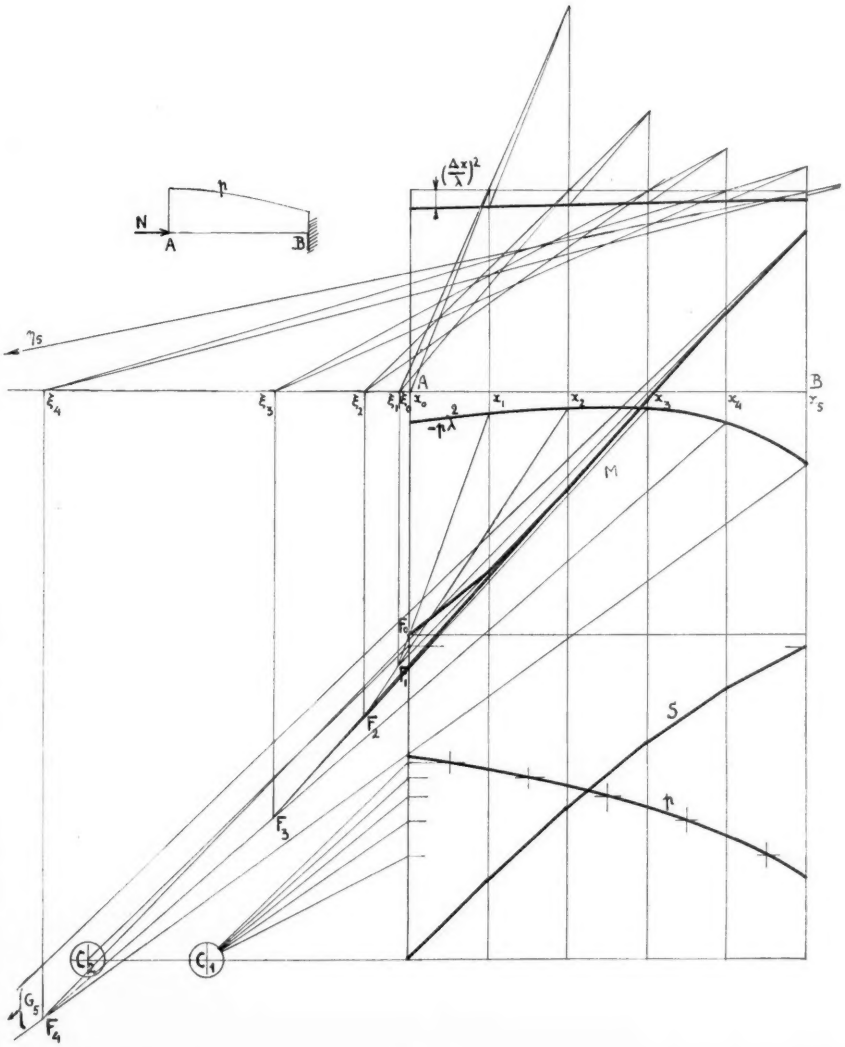

Fig. 7.

If the beam is free in A (Fig. 5) and built-in in B, the shear S is known in A. It is zero if there is no concentrated load in this point. Integrating Eq. 1

$$S_B = S_A + \int_A^B p\,dx \quad . \quad . \quad . \quad . \quad . \quad (18)$$

But, in B the slope z of the elastic line is zero, thus Eq. 2 reduces to

$$M'_B = S_B \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

which is the second condition.

6. Beam Simply Supported at Both Ends.

The beam AB is divided into equal parts, the length of which is sufficiently small against λ (Fig. 6). The bending moment being zero at the end A, the fixed point F_0 of the first chord coincides with the origin. The other fixed points are found by repeating the construction of Fig. 3. It has been supposed that there is a tensile load.

Since the bending moment is zero at the end B the last chord is F_4B. Joining the left end of it to F_3 one gets the next chord and so on. It is easy to draw the tangents if they are wanted, but usually the curve is sufficiently well described by its chords.

7. Beam Simply Built-in (Fig. 7).

Let it be supposed that A is free and B built-in, and that the axial force is compressive. The fixed points of the chords are found as previously. The fixed point G_5 through which passes the tangent at the abscissa x_5 is determined too. The p curve is integrated graphically, using the intervals Δx, with the aid of the pole C_1. The integral is the S curve and its initial constant is known since S_A is given (here zero). A second pole of integration C_2 is chosen in such a way that the scale of the second integral is the same as that of $p\Delta^2$. But it is sufficient, here, to find the final slope of that integral, *i.e.*, S_B. Tracing a straight line of that slope by G_5 one has the final point of the M curve and the successive chords are found without difficulty.

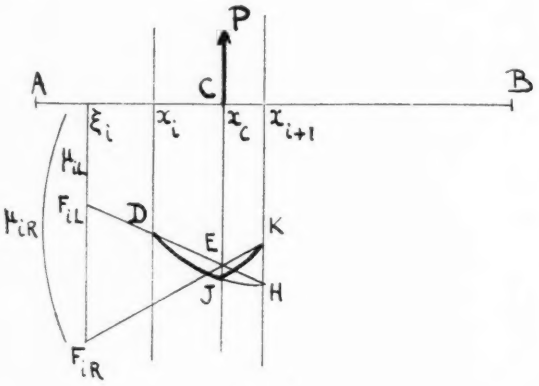

Fig. 8.

8. Concentrated Loads.

Let a concentrated load P be applied in C (Fig. 8). The previous calculations apply to both parts AC and CB of the beam, but not to the point C itself. The bending moment is the same on both sides of C, but there is a discontinuity in

its derivative. If S_L and S_R are the shears immediately to the left and to the right of C

$$S_R - S_L = P.$$

Since there is no discontinuity in the slope of the beam, the discontinuity in the derivative of M equals the concentrated load (Eq. 2). If, without P, the chord were $F_{iL}DEH$ and the M curve DJE the left part is unchanged, but on the right side of C a linear function must be added; this is simply done by transferring H to K with

$$HK = P\,(x_{i-1} - x_C).$$

Thus, if the left chord passes through the fixed point F_{iL} the right chord passes through another fixed point F_{iR} of same abscissa defined by

$$\mu_{iR} - \mu_{iL} = -P\,(x_c - \xi_i).$$

The construction can be carried on with F_{iR} as usual.

9. Concentrated Moment.

Let a concentrated moment M_c be applied in C (Fig. 9). There is a discontinuity in the M curve, but the shear is the same on both sides of C. Thus, if the chord passed in F_{iL} in the absence of M_c, the part of it on the right side of C has to be translated by the amount M_c. The fixed point of the chord becomes F_{iR} and the construction is carried on towards the right as usual.

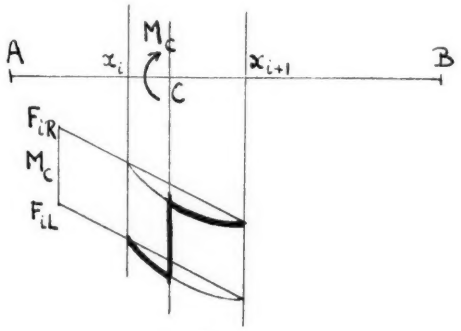

Fig. 9.

10. Deformations of the Beam Simply Supported at Both Ends.

Eq. 2 shows that

$$N\chi = M' - S \qquad . \qquad . \qquad . \qquad . \qquad . \qquad (20)$$

As soon as the bending moment is known its derivative M' is easily found. The shear curve is, on the other hand, the integral of the p curve.

$$S = S_A + \int_A^x p\,dx.$$

Integrating Eq. 20 one has

$$N\,(w - w_A) = M - M_A - xS_A - \int_A^x dx \int_A^x p\,dx.$$

The three constants S_A, M_A and w_A are determined by the boundary conditions. The bending moment in A is known; if there is no cantilever end $M_A = 0$; the

deflection is zero at A: $w_A = O$ and at B, *i.e.*:

$$O = M_B - lS_A - \int_A^B dx \int_A^x p dx$$

this condition determines S_A.

The conditions are easily expressed graphically as the following example will show.

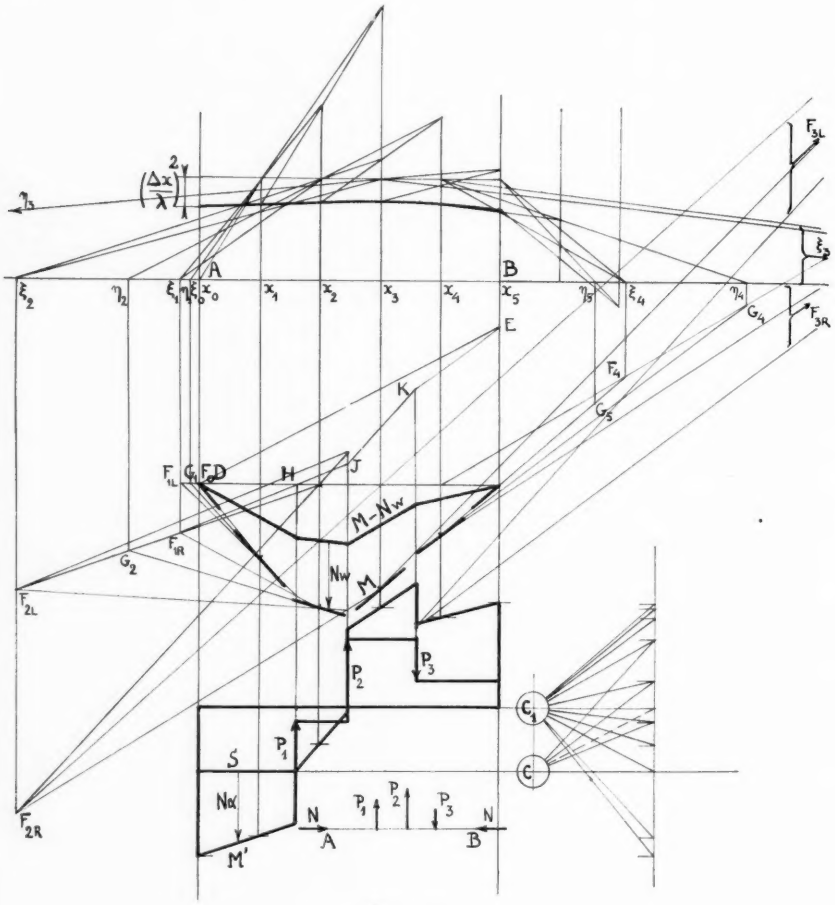

FIG. 10.

In the case of Fig. 10 the beam is pin-jointed and loaded with three concentrated loads, P_1, P_2 and P_3, the axial load being a compression ($N < O$). The abscissæ of the fixed points F and G are determined first (ξ and η). Then the S curve is traced by integrating the loads. The initial constant is indeterminate. The curve is again integrated with the aid of the pole C; the initial constant is zero, but the curve $DHJKE$ thus found must be corrected by the adding of a linear function, determined by the condition that the final value is zero. A parallel to DE is traced by C; it determines on the axis of integration

the level of the line of reference for the S curve. A second pole C_1 is chosen on that line and the integral found with this pole is the true $(M - Nw)$ curve.

Now the fixed points F are determined successively. When F_{1L} is known, F_{1R} is found by drawing a parallel to the first chord DH of DE. By its intersection with the vertical of P_1 a parallel to the second chord HJ is traced, which gives F_{1R}, since the difference of slope between the chords of DE equals the discontinuity of slope of the M curve.

In the same way when F_{2L} is known a parallel to the second chord HJ is drawn, and by its intersection with the vertical of P_2 a parallel to the third chord JK. F_{2R} lies on this. And so on.

Each fixed point G lies on the straight line joining the fixed points of the adjacent chords (F_0F_{1L}, $F_{1R}F_{2L}$, $F_{2R}F_{3L}$ and $F_{3R}F_4$). Since there is no distributed load the initial and final tangents coincide with the initial and final chords.

The M curve is easily determined as previously (Fig. 6), commencing by the right. The chords are traced first, then the tangents (the curve itself has not been traced). The difference between M and $M - Nw$ is Nw, in the present case negative. Since N is negative the deflection is positive.

The parallel to the tangents drawn by C_1 determine on the axis of integration the values of M'; the curve presents the same discontinuities as the S curve. The difference between M' and S is Nz. In the present case z is positive on the left hand side and negative on the right hand side.

11. Deformation of the Beam Simply Built-in.

The equations are the same as in the previous case but the initial constants are determined differently. The bending moment M_A and the shear S_A equal the moment and force applied on the free end A. The deflection is zero in B, *i.e.*,

$$-Nw_A = M_B - M_A - lS_A - \int_A^B dx \int_A^x p\,dx$$

which determines w_A.

In the case of Fig. 11, the transverse loads consist of a distributed load p and a concentrated load P. The axial force is tensile. The abscissæ ξ and η of the fixed points are determined first, as well as ζ. The p curve is then integrated with the aid of the pole C; the curve thus obtained is the S curve. A second pole of integration C_1 is chosen in such a way that the scale of the second integral is the same as that of pA^2. Now the fixed points are determined successively from F_0. When F_{2L} is known a line is drawn through it, parallel to C_1a, the level of a being that of the S curve immediately on the left of P. Through the intersection D of that line with the vertical of P, a parallel is drawn to C_1b, the level of b being that of the S curve immediately on the right of P. F_{2R} lies on that line. The following fixed points are found as usual.

The slope of the M curve in B is S_B, it is thus determined by joining C_1 to point d, the level of which is that of S_B (*cf.* Fig. 7). A parallel to it drawn by G_3 determines the final point E of the M curve. The last chord is F_4E and the other chords are determined successively. The tangents pass through the fixed points G. The initial tangent is determined as in Fig. 4. The curve itself has not been drawn to avoid overloading of the figure.

The S curve is then integrated, starting from E, towards the left; this gives $M - Nw$. The differences of ordinates between the two curves represent thus Nw ($w > o$). Through C_1 parallels are drawn to the tangents of the M curve; they determine on the axis of integration the values of M', and the M' curve is drawn easily. It presents, on the vertical of P, the same discontinuity as the S curve. The differences of ordinates between the two curves represent Nz ($z < o$).

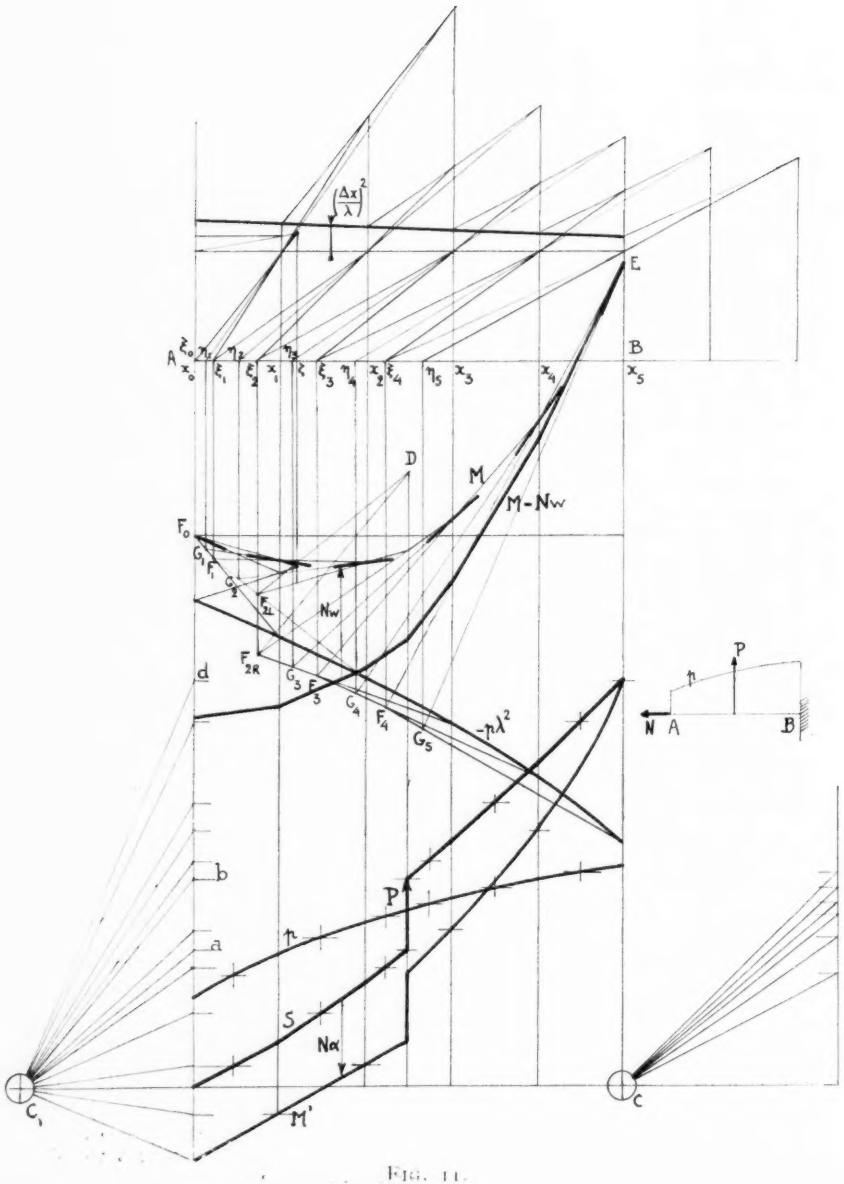
$\left(\frac{\Delta x}{\lambda}\right)^2$
E
A
B
D
M
M-Nw
F_0
Nw
d
$-p\lambda^2$
P
p
N A B
b
a
S
N_α
M'
C_1
C

FIG. 11.

Chapter III.

The Single Beam with Redundant Supports.

12. The Beam Simply Supported and Built-in.

Let it be supposed that the beam AB is simply supported at A and built-in at B. The support A applies on the beam a shear S_A. If the support is removed the state of loading is unchanged if an external force S_A is applied on A, together with the external load; and its magnitude is determined by the condition that the deflection in A is zero.

The transverse loads may be studied separately, and their effects added, provided that, for each, the axial force N is taken into account. The external load has been studied previously. The effect of $S_A = 1$ is studied exactly in the same way, but the construction of Fig. 11 is greatly simplified. Fig. 12 shows what it becomes in the case of compression.

Let α^S and w^S be the slope and deflection in A due to an unit load $S_A = 1$ and α^P, w^P the slope and deflection due to the external loads. The deformation under the combined action of the external loads and a load S_A of any value will be

$$\left.\begin{aligned} \alpha &= S_A \cdot \alpha^S + \alpha^P \\ w &= S_A \cdot w^S + w^P \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

The shear S_A is determined by the condition that $w = 0$.

13. The Beam Doubly Built-in.

If the beam AB is built-in in A and in B, the supports of the left end apply to it a shear S_A and a bending moment M_A. If these supports are removed the state of loading is unchanged if external loads S_A and M_A are applied in A, together with the external loads; their magnitudes are determined by the condition that both the slope and the deflection of the beam are zero. The effect of the external loads, and of the shear S_A have been studied previously. The effect of the moment M_A is studied easily and Fig. 13 shows how Fig. 11 is simplified in that case (tension).

Let α^M and w^M be the slope and deflection in A due to an unit moment $M_A = 1$. By the law of reciprocity

$$w^M = -\alpha^S.$$

The minus sign results from the conventions.

The deformations in A under the combined action of the external loads, a shear S_A and a bending moment M_A are

$$\left.\begin{aligned} \alpha &= M_A \cdot \alpha^M + S_A \cdot \alpha^S + \alpha^P \\ w &= M_A \cdot w^M + S_A \cdot w^S + w^P \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (22)$$

The shear S_A and the bending moment M_A are determined by the conditions

$$\alpha = w = 0.$$

Chapter IV.

Buckling.

Buckling occurs when there is, under compression, a state of non-linear equilibrium without any transverse load.

14. Beam Simply Built-in.

When there is no transverse load all the fixed points lie on the x axis, and each of them is on the left side of the previous one (*cf.* Fig. 7). As the compression increases their mutual distances grow, and there is a load for which the fixed point of the last tangent is removed to an infinite distance. The shear at the right end is obviously zero and consequently the slope of the M curve on the right end is zero. As long as the fixed point of the last tangent is at a

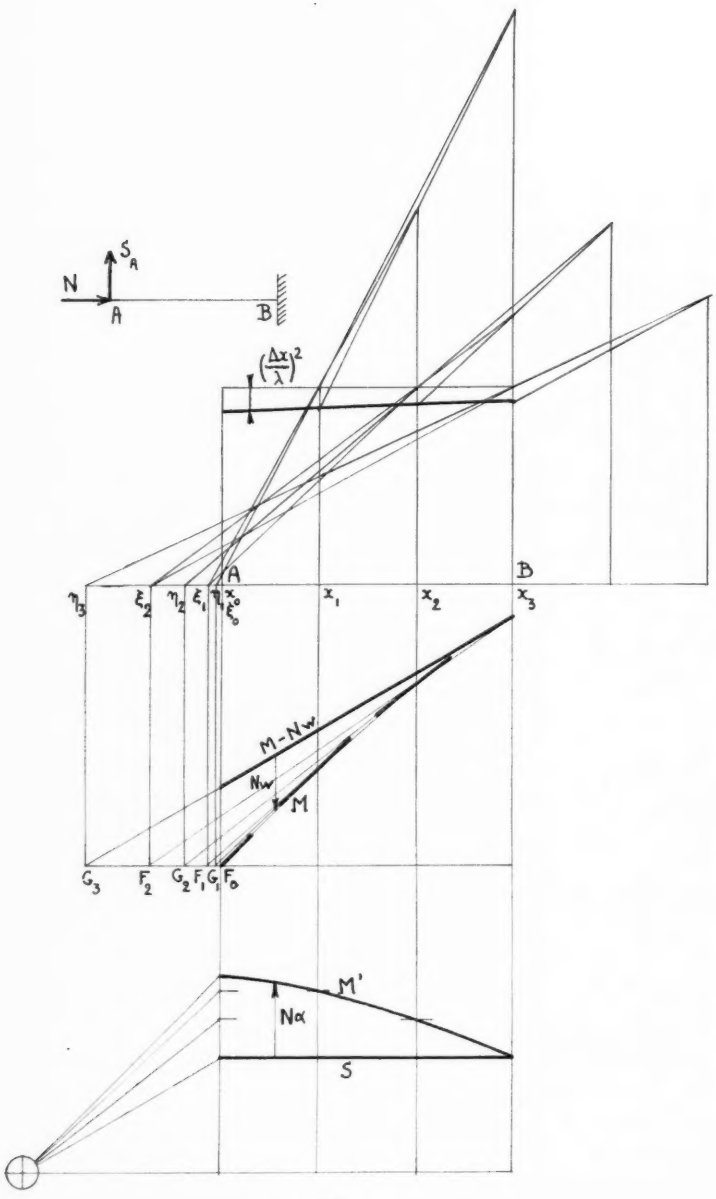
N
S_A
A
B
$\left(\frac{\Delta x}{\lambda}\right)^2$
A
B
ξ_3
ξ_2
ξ_1
ξ_0
x_1
x_2
x_3
M-Nw
Nw
M
G_3
F_2
G_2
F_1
G_1
F_0
M'
Nα
S

FIG. 12.

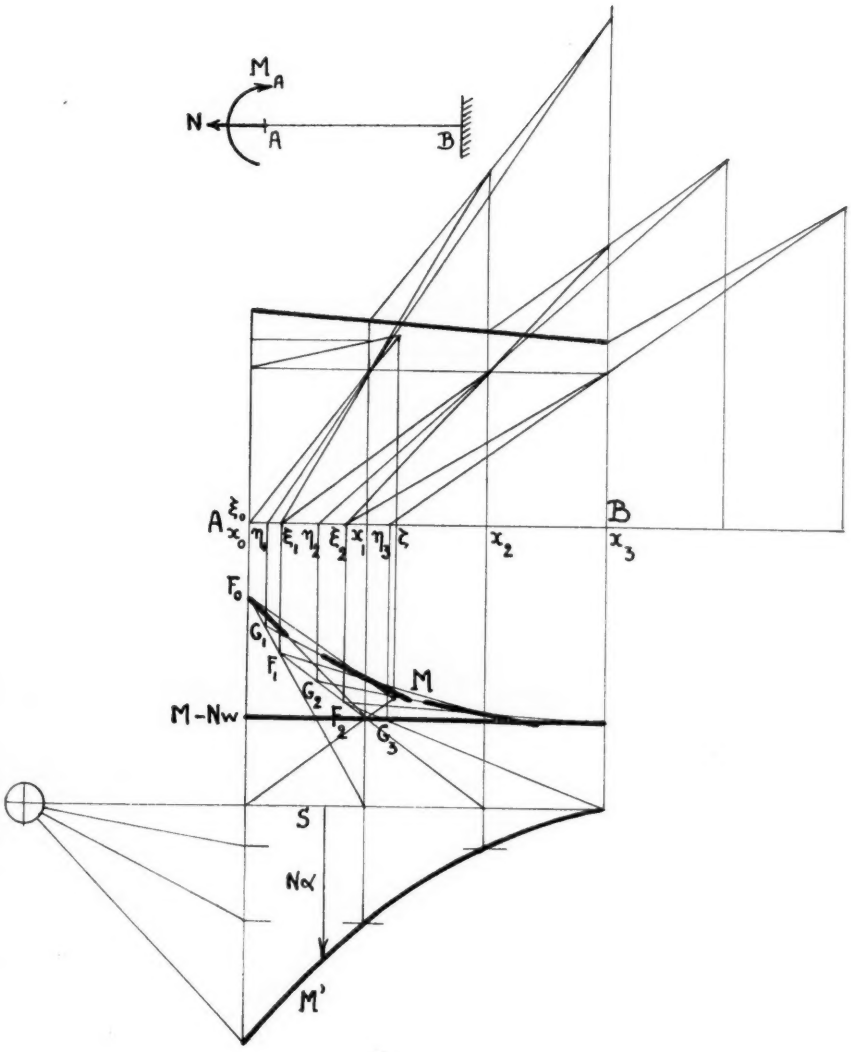
M
A
N
A
B
A
B
ξ_0
x_0
η_1
ξ_1
η_2
ξ_2
x_1
η_3
ζ
x_2
x_3
F_0
G_1
F_1
G_2
F_2
G_3
M
M-Nw
S
Nα
M'

FIG. 13.

finite distance the bending moment must be zero in B and along the whole length. But when it reaches an infinite distance the value of M in B may assume any value. The shape of the M curve is well defined, but its height is indeterminate. The corresponding load is the buckling one.

15. Beam Simply Supported at Both Ends.

As in the previous case all fixed points lie on the x axis (*cf.* Fig. 10). If the compression becomes larger than the previous critical value some of the fixed points come towards the left from infinity on the right hand side. The bending moment at the right end of the beam is zero. As long as the fixed point of the last tangent is on the right of B the moment must be zero along the whole beam, but as soon as it reaches the point B it is possible to draw an M curve of given shape but indeterminate height. This corresponds to buckling.

16. Beam Simply Supported and Built-in.

In this case the slope of the beam at the simply supported end A, makes a transverse reaction appear. The diagrams are those of Fig. 12. The deflection in A must be zero without being zero along the whole length; this is possible only if the fixed point of the last tangent (here G_3), having been removed to an infinite distance comes back from the left as far as F_0. The corresponding load is the buckling one. The condition is expressed analytically by

$$w^S = 0.$$

17. Beam Doubly Built-in.

When the beam is doubly built-in the conditions which determine M_A and S_A in the absence of any transverse load are (*cf.* Eq. 22)

$$\left.\begin{aligned} 0 &= M_A \cdot z^M + S_A \cdot z^S \\ 0 &= M_A \cdot w^M + S_A \cdot w^S \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (23)$$

They admit a solution, different from $M_A = S_A = 0$ if

$$z^M \cdot w^S - z^S \cdot w^M = 0.$$

This condition characterises the buckling load. Graphically the condition is expressed by the fact that, the load being still greater than in the preceding case, the fixed point of the last tangent moves a second time towards infinity.

Practically the buckling load will be found in each case by a few trials. It is known to be intermediary between the buckling loads of the struts with constant section which have respectively the minimum and the maximum section of the beam. A diagram will be made of the position of the last fixed point as a function of the compression. The two limit values and perhaps a third intermediary one will be sufficient to determine with accuracy the buckling load of the beam.

Conclusion.

All the problems connected with the beams under tension or compression can be treated nearly as simply as those concerning the beams simply bent; the accuracy is of the same order.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES

MARCH, 1941.

Annual General Meeting.

The Annual General Meeting of the Society will be held in the Offices of the Society, at 4, Hamilton Place, London, W.1, at 3 p.m., on Saturday, March 29th, 1941. An Agenda will be sent to all voting members.

Journal Publication.

On account of wartime conditions will members please note that the JOURNAL will be published between the first and tenth days of the month?

Wilbur Wright Memorial Lecture.

The 29th Wilbur Wright Memorial Lecture will be given by Mr. J. T. Trippe, M.A., President, Pan American Airways Inc., on Thursday, May 15th, at 6.30 p.m., in the Lecture Theatre of the Institution of Electrical Engineers, Victoria Embankment, W.C.2. The subject of the lecture will be "Ocean Air Transport."

Members' Subscriptions.

Members are reminded that their subscriptions were due on January 1st, 1941. The Council hope that every member will make an effort to pay his subscription as early as possible to save postage on reminders. The rates are:—

	Home.				Abroad.			
	£	s.	d.		£	s.	d.	
Founder Member	2	2	0		2	2	0	
Fellow	4	4	0		3	3	0	
Associate Fellow	3	3	0		2	2	0	
Associate	*2	2	0		*2	2	0	
Graduate	2	2	0	(21-26 years)				
	2	12	6	(26-28 years)				
Student	1	1	0		1	1	0	
Companion	2	2	0		2	2	0	

* £1 1s. 0d. without Journal.

Binding of Journals.

Arrangements have been made for Members' Journals to be bound at the special price of 4s. 6d. per volume for the current volume and 5s. 6d. for back volumes. Journals should be sent direct to the Lewes Press, Friars Walk, Lewes, Sussex, and a remittance to the Society.

Associate Fellowship Examinations.

New regulations and syllabuses for the Associate Fellowship Examinations have been prepared, and notice is herewith given that these new regulations and syllabuses will come into force at the examination to be held in May, 1943. Until that date examinations will be held under the existing syllabuses.

Associate Fellowship Examination Results.

The following Candidates were successful in the December, 1940, Examinations:

J. Bekassy	Design (Aircraft) (First Place). Aerodynamics (First Place). Applied Mathematics.
G. H. I. Cornwell ...	Pure Mathematics.
D. G. S. Grant ...	Aircraft Materials.
P. B. Locke	Theory of Machines.
G. M. M. Magill ...	Design (Aero Engines) (First Place). Applied Mathematics.
R. B. Marsh	Theory of Machines. Applied Mathematics (First Place).
D. M. McElhinney ...	Strength of Aeronautical Materials and Structures.
A. R. Pitt	Pure Mathematics (First Place).
J. McA. Rainey ...	Design (Aero Engines). Theory of Machines. Applied Mathematics.
Miss B. M. Rimmer...	Aircraft Instruments (Theory and Design). Aerodynamics. Pure Mathematics.
B. L. Rodger	Design (Aero Engines). Theory of Machines (First Place). Applied Mathematics.
A. R. Sarup	Aerodynamics.
L. A. Teff	Design (Aero Engines). Theory of Machines Applied Mathematics.
R. W. Thomas ...	Applied Mathematics.
D. B. Wallis	Theory of Machines. Applied Mathematics.
D. H. Whaley ...	Design (Aero Engines). Applied Mathematics.
R. T. Wood	Design (Aircraft). Strength of Aeronautical Materials and Structures.

Baden-Powell Memorial Prize.

The Baden-Powell Memorial Prize has been awarded to Mr. J. Bekassy, who was considered by the Examiners to be the best student in the December, 1940, Associate Fellowship Examinations.

Election of Members.

Associates.—Charles William Leitch, Norman Russell McMillan, George Michael Scales (from Student), Arthur John Wilkinson.

Graduates.—Stanley Charles Caliendi (from Student), Peter Linton Cronbach (from Student), Norman Jesse Flood Gunn, John Victor Price Williams (from Student).

Students.—Harry Bentley, Harry Edmund Brand, Arthur Whitten-Brown, Laurence Sydney Edwards, Augustine Kennedy, Ian Robert Lyon, John Alan Parfitt, Raymond Ernest Wigg.

Acknowledgments.

The Council acknowledges with grateful thanks the gift of books for the Library from the University College Library, Southampton.

Additions to the Library.

Pamphlets in italics, with location reference following in brackets. Books marked * are not available for loan.

B.a.232.—A.P. (1261). Supermarine Southampton Boat Seaplane, Mark II. 1929.

*B.g.91.—Association Internationale des Registres (A.I.R.), No. XVII. 1939.

B.g.92.—*Aircraft Recognition (Suggestions for Home Study). R. Saville Sneath. (Articles from "Newnes Practical Mechanics," Nov.-Dec.,* 1940.) (Y.3.ii.G.)

*B.g.93-97.—French Aircraft in 1921, 1923, 1926, 1928, 1938. (Special issues of French Magazine "L'Air.")

B.e.38.—*Scale Model Aircraft (Series): Nos.* 7 (*HE* 113), 8 (*Lockheed P.*38), 9 (*Breda* 88). *James H. Stevens. (Articles from "Newnes Practical Mechanics,"* 1940-41.) (Y.10.d.3.)

BB.b.87.—*Aircraft Structures. A G. Pugsley. (Article in "The Structural Engineer," Jan.,* 1941.) (Y.8.a.15.)

D.b.161.—*Empire Flying Boat Operations: Continuance under War Conditions. W. Hudson Fysh. (Reprint from "Shipping, Commerce and Aviation of Australia,"* 30/10/40.) (Y.6.a.27.)

D.c.83. *Report on the Aerodrome Facilities of London. Air Ministry. (Cmd.* 1,816.) 1923. (PD.4.a.1.)

D.e.29.—*Report on Government Financial Assistance to Civil Air Transport Companies. Air Ministry. (Cmd.* 1811.) 1923. (PD.2.b.2.)

D.e.30.—*Agreement providing for the formation of a Company to be called Imperial Air Transport Company, Ltd. Air Ministry. (Cmd.* 2010.) 1923. (PD.2.b.3.)

D.e.31.—*Interim Report of the Air Mails Committee. Air Ministry. (Cmd.* 2038.) 1924. (PD.2.b.4.)

E.b.84.—Theory of Plates and Shells. S. Timoshenko. McGraw Hill. 1940. 42/-.

*G.b.3.—*British Standard Specifications.* 1940. 1/- each.
6A.1. Hexagonal Headed Bolts (Low Tensile Steel).
2A.15. Hexagonal Headed Bolts (High Tensile Steel).

*G.b.33.—Hiduminium Technical Data. High Duty Alloys, Ltd. 1941.

G.e.J.15.—The Technology of Magnesium and its Alloys. Dr. A. Beck. F. A. Hughes and Co. 1941. 30/-.

G.f.20.—*Technical Information on Soft Solders. C. W. Hart. (Stencilled Notes.) Fry's Metal Foundries.* 1941. (Y.13.b.6.)

L.b.37.—Flight Handbook (2nd Ed.). W. O. Manning and Technical Staff of "Flight." Flight Publishing Co. 1941. 4/-.

L.d.63.—Nachrichten für Luftfahrer, Nos. 1-12. 1934. Reichsluftfahrtministerium, Berlin.

M.d.5.—*Our Searchlight System. (Article in "Newnes Practical Mechanics," Jan.,* 1941. (Y.17.c.S.)

N.a.65.—Abstracts of Dissertations approved for the Ph.D., M.Sc. and M.Litt. Degrees in the University of Cambridge. (1939-40.) University Press, Cambridge. 1941.

R.c.257.—The Conquest of the Air. Alphonse Berget. Wm. Heinemann. 1909.

R.c.258.—The Art of Aviation (2nd Ed.). R. W. A. Brewer. Crosby Lockwood. 1911.

R.d.37.—The Aeroplane Speaks (6th Ed.). H. Barber. McBride, Nash and Co. 1918.

R.d.38.—*Aircraft: The New British Industry. Supplement to "Truth," Sept.* 5, 1917. (PR.2-17.)

*R.f.66.—*Rebuke to Science* (*Pénaud-Gauchot Airplane Patent*, 1876). *Marc Hanlon.* (*Photostat of article in "Western Flying," Oct.*, 1940.) (Y.11.iv.a.21.)

*R.f.67.—Wonders of World Aviation. Edited by C. Winchester and J. L. Pritchard. Amalgamated Press, Ltd. 1938. (Weekly parts, bound in one Vol.)

S.d.72.—Defence Against the Night Bomber. N. Pemberton-Billing. Robert Hale. 1941. 2/6.

S.d.73.—*The Balloon Barrage Explained.* (*Article in "Newnes Practical Mechanics," Dec.*, 1940.) (Y.17.c.B.)

S.d.74.—*Bombing by Aircraft.* (*Article in "Newnes Practical Mechanics," Nov.*, 1940.) (Y.17.c.B.)

T.b.73.—Best Flying Stories. Various Authors, edited by Norman Macmillan. Faber and Faber. 1941. 8/6.

*WB.19a.—Abstracts from the Scientific and Technical Press, 1940. (Annexe to Journal of the Royal Aeronautical Society.) Issued by R.T.P., Air Ministry.

*WG.2.—Flugsport. (German Magazine.) Bound Volumes, 1911-1918. (Incomplete.)

*X.c.E.2.—Armea Terminaro. (Esperanto Glossary of Military Terms.) E. D. Durrant. Internacia Esperanto-Ligo. 1940. 9d.

Y.24.—*Publications of the Tin Research Institute* (1940-41).

No. 97. Crystal Boundaries in Tin. Bruce Chalmers.

No. 98. Influence of the Steel-Base Composition on the Rate of Formation of Hydrogen-Swells in Canned Fruit Tinplate Containers. T. P. Hoar, T. N. Morris and W. B. Adam.

No. 99. Metal Sprayed Bearings for High Speed Operation. Harry Shaw.

No. 100. Tin Electrodeposition and its Field in Industry. S. Baier and W. H. Tait.

No. 101. Factors Influencing the Formation of a Smooth Coating of Tin on Copper by Hot Dipping. Bruce Chalmers and R. H. Wadie.

No. 102. Hot-Tinning. C. E. Homer.

J. LAURENCE PRITCHARD, *Secretary and Editor.*

RECENT FOG INVESTIGATIONS.

SVERRE PETTERSSEN.

Massachusetts Institute of Technology.

FOURTH WRIGHT BROTHERS LECTURE.

Presented before the Institute of the Aeronautical Sciences at Columbia University, New York, December 17, 1940. Reprinted by courteous permission of the Editorial Board of the Institute of Aeronautical Sciences.

PART I.

THE PHYSICS OF FOG.

Fog is the result of a condensation process near the earth's surface when the air is cooled below its dew-point temperature by one or more of the processes which will be discussed in the second part of this paper.

NUCLEI OF CONDENSATION.

The classical experiments of Wilson (1) showed that some types of particles, now called *nuclei of condensation,* must be present in the air if condensation is to occur with a reasonable degree of supersaturation. Wilson found that about eight-fold supersaturation would be needed to initiate condensation in perfectly pure air. By ionizing the air, he was able to show that positive and negative ions could serve as nuclei of condensation, and that condensation would then be initiated at about four- to six-fold supersaturation.

It was then thought that the ions were the nuclei responsible for the condensation leading to the formation of fogs and clouds. However, no evidence has been found to support this view. In fact, it has been found that such degrees of supersaturation are never attained in the atmosphere, and that fogs and clouds form when the air is close to the saturation point. Since dust particles are always present in the atmosphere in abundant amounts, it was next thought that these particles could act as condensation nuclei.

The extensive investigations of Aitken (2) led to a much more complete understanding of the nature of the condensation nuclei. Aitken developed an instrument which was originally called a *dust counter* for determining the number of nuclei in a unit volume of air. In using this instrument, he found that the number of condensation nuclei was almost independent of the amount of dust in the air. From this he concluded that the atmosphere normally contains a more active type of nuclei than ordinary dust. Extending his experiments, he found that most of the dust particles were inactive as condensation nuclei, but that certain particles, which were hygroscopic, acted as nuclei. These particles were composed of inorganic salts, sulphur trioxide and other products of combustion.

Aitken's discoveries were considerably clarified by Köhler (3) on the basis of a theoretical treatment by Thomson (4), who had found that the amount of supersaturation required to induce condensation on a small particle was an inverse function of the radius of curvature of the particle. However, particles which are hygroscopic induce condensation to occur even below the saturation point, and hence the condensation required by the cooling of the air takes place on the

hygroscopic nuclei, and such high degrees of supersaturation as are required for inducing condensation on the inactive nuclei and ions will not occur.

By means of Thomson's formula and data on the saturation vapour pressure with respect to hygroscopic materials, Köhler computed curves of the type shown in Fig. 1. The hydroscopic material selected was sodium chloride, and the curves show the relative humidity required to induce condensation on nuclei of various sizes.

The Aitken nucleus or " kern " counter determines the number of nuclei in an air sample by subjecting it to a rapid expansion. This causes a considerable degree of supersaturation, and the drops which form around each nucleus fall on to a ruled slide where they may be counted. Assuming that nuclei of all sizes exist in the atmosphere, it is evident from Fig. 1 that the number of nuclei as measured with this instrument is dependent upon the degree of supersaturation produced. Since the instrument is normally operated so as to give almost instantaneously a much higher degree of supersaturation than ever occurs in the atmosphere, the number of nuclei as measured is always considerably greater than the number which become active in natural condensation processes. For a given amount of water condensed the rate at which the initial condensation takes place largely determines the number of nuclei which will become active. If the rate of condensation is very slow only the larger nuclei will become active, while if the initial rate of condensation is rapid more nuclei will be required, and thus some of the smaller ones will become active. Fog is usually formed as a result of a relatively slow condensation process, and hence only a very small fraction of the available nuclei become active. Thus, although there are usually from several hundred to several thousand nuclei per cc. available, the number of fog particles seldom exceeds 100 per cc. In the case of convective clouds where the condensation process is much more rapid, as many as 500 to 1,000 drops per cc. may be formed.

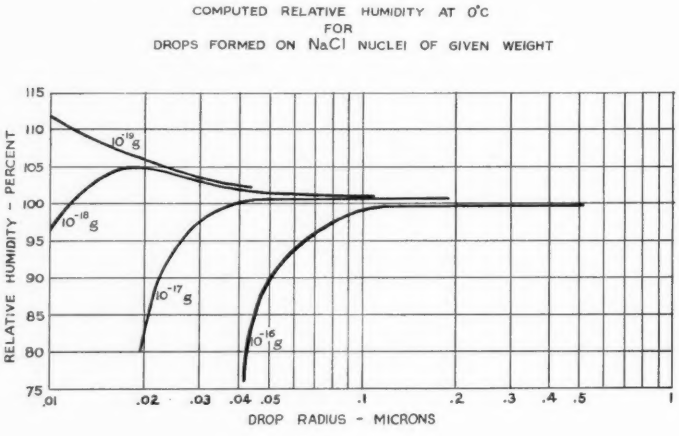

FIG. 1.

All available evidence indicates that an appreciable degree of supersaturation is seldom, if ever, attained in the atmosphere, condensation occurring as soon as, or even slightly before, saturation is reached.

In an effort to confirm the theory that condensation usually occurs on hygroscopic particles, samples of cloud and fog water have been chemically analysed by several investigators. After the fog is formed, the original nuclei are so diluted that the analysis is extremely difficult and only the principal constituents

can be determined. Fogs occurring over or near the ocean are found to contain measurable quantities of chloride, probably in the form of sodium and magnesium chlorides, which are hygroscopic constituents of sea water. It has been found by Houghton and Bemis that fog water contains relatively large quantities of sulphate, some of which is apparently associated with metallic ions and some with the hydrogen ion. It is believed that these derive from the sulphur contained in coal and other fuels which, when burned, produce sulphur dioxide which then oxidises to form the highly hygroscopic sulphur trioxide. These measurements may be taken as an indication of the correctness of the assumption that hygroscopic substances constitute the principal active atmospheric nuclei.

Size of Nuclei and Fog Droplets.

Chemical analyses of fogs show that the amount of hygroscopic substance in a fog is about 100 milligrams to a litre of fog water, or one part in ten thousand by weight. The average diameter of a fog droplet is about 40 microns (see Fig. 2). Assuming that the dry nucleus has a density of about 2, a simple

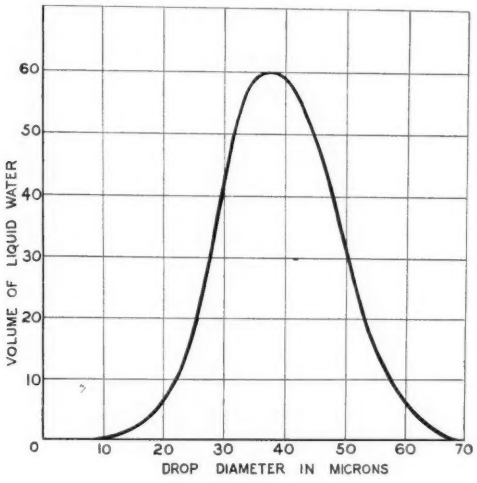

Fig. 2.

computation shows that the diameter of the dry nucleus is of the order of magnitude of about 1 or 2 microns. In comparison, it may be mentioned that the diameter of ordinary rain drops varies from about 500 to 4,000 microns.

Since the diameters of the condensation nuclei are of the order of magnitude of 1 to 2 microns, it follows from Fig. 1 that no supersaturation is required to initiate condensation. This result confirms the conclusion, based on direct observation, that fog forms as soon as the saturation temperature is attained. In industrial areas, where hygroscopic particles are particularly plentiful, fogs have been observed to form and persist even though the saturation point is never reached. Fogs of moderate density may under such circumstances persist with relative humidity of about 1 or 2 per cent. below saturation.

The Condensation Process.

We have seen that condensation is initiated on the largest and most active condensation nuclei. However, when the drop grows in size, its curvature decreases, and the effect of curvature on the saturation pressure soon becomes negligible. Furthermore, through growth the drop becomes so diluted that it

almost ceases to act as a hygroscopic substance. The condensation then proceeds in the same way as over a plane water surface.

The condensation of water vapour is a diffusion phenomenon. The steady state solution of the general equation for diffusion was found by Houghton (5) to be

$$t = \frac{d_2^2 - d_1^2}{8\pi k(\rho - \rho_0)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where t = number of seconds required for a drop of diameter d_1 to grow to diameter d_2.

k = coefficient of molecular diffusion of water vapour.

ρ = the ambient density of water vapour.

ρ_0 = the saturation water vapour density at the surface of the drop.

Since ρ_0 is usually equal to or slightly greater than the saturation water vapour pressure over a plane water surface, it is evident that there must be a certain amount of supersaturation if the drop is to grow. This supersaturation will be established if the air is cooled. Computations made on the basis of reasonable rates of cooling and an average number of drops per unit volume show that this supersaturation need be only a fraction of a per cent.

From Houghton's steady state solution of the diffusion equation, we may compute the rate of growth of the droplets. It will be seen that the small drops grow more rapidly than the large drops, so that there is a tendency for all drops to attain the same size. A newly formed drop will be slightly larger than a condensation nucleus, and an average fog drop will be about 40 microns in diameter. Table I shows how drops of various diameters will grow during equal intervals of time to become average sized fog drops of almost uniform size.

TABLE I.

Growth of Fog Droplets.

Initial Drop Diameter (Microns)	Drop Diameter (Microns) after Identical Time Intervals.	Ratio.
0.2	40.0	200.0
2	40.0	20.0
4	40.2	10.1
6	40.5	6.7
8	40.8	5.1
10	41.2	4.1
20	44.7	2.2
30	50.0	1.7

Under ordinary atmospheric conditions the growth of the drop diameters computed in Table I would require a time interval of about 100 seconds. A similar computation shows that it would take a fog droplet about 24 hours to grow to the size of an average rain drop. From this we may conclude that, whereas the fog droplets form through condensation, the rain drops form through coalescence of cloud droplets.

COLLOIDAL STABILITY.

From the point of view of physical chemistry, fog may be regarded as an aerosol in which the particle separation is large compared with the drop diameter. Any process that tends to increase the size of the elements at the expense of the others, will ultimately result in the formation of drops which are too large to be kept afloat in the air. The fog is then colloidally unstable, and precipitation will fall from the fog.

There are five factors which control the colloidal stability of the fog, namely, the electric charge, the motion, the temperature, the size of the drops and the phase of the condensed water.*

(*a*) Usually the fog droplets are electrically charged, and if neighbouring drops have opposite charges, the forces of attraction would tend to cause coalescence. The distance between the drops is, however, so large and the charge so small, that no appreciable instability results.

(*b*) If small-scale turbulence is present, adjacent drops may be caused to collide in the boundary regions of the eddies. This effect is difficult to evaluate, but it appears to be small in most cases.

(*c*) The action of turbulence may also cause drops of different temperature to be brought into proximity. Since the saturation vapour pressure is higher over warmer than over colder water, there would be supersaturation over the colder drops and saturation deficit over the warmer drops. This would tend to cause the warmer drops to evaporate and the colder drops to grow. Since fogs usually occur under isothermal conditions, this effect is negligible. Moreover, as has been shown by Petterssen (9), the effect of different drop temperatures can be appreciable only when the air temperature is high, because the saturation vapour pressure varies but little when the air temperature is low.

(*d*) The variation in drop size will tend to cause colloidal instability, for the saturation vapour pressure is lower over small drops than over large drops. This will cause supersaturation over the larger drops and subsaturation over the smaller drops, with the result that the larger drops thrive at the expense of the smaller drops. However, the variation in drop size is so small and the drop diameters that occur in fogs are such that this effect is negligible.

Fog drops are sufficiently large to have an appreciable velocity of fall through the air. Since the velocity of fall is proportional to the square of the drop diameter, there will be a moderately wide range of falling velocities. This may cause the larger drops that fall to collide with smaller drops, and this may cause slight precipitation (drizzle) to fall from the fog. This particularly happens when the fog layer is sufficiently deep. The drizzle drops have diameters varying from 100 to 500 microns.

(*e*) On account of the smallness of the drops, a water fog may persist at temperatures as low as -10 to -20°C. At low temperatures, ice crystals begin to form, and when ice crystals are mixed with water droplets, the fog becomes colloidally unstable, because the saturation pressure over the ice crystals is noticeably lower than over the water droplets. In a fog consisting of both water and ice the vapour pressure will adapt itself to some value between the two saturation pressures. There will then be supersaturation over the ice particles and subsaturation over the water droplets, with the result that the drops tend to evaporate while the ice particles increase in size. This effect is of great importance in the nimbus clouds and is the most potent cause of the release of precipitation from clouds (Bergeron (7*a*)). As far as fogs are concerned, the effect of the presence of ice and water is most noticeable when there is fog over snow-covered ground. As will be explained in the second part of this paper, the fog will then have a tendency to dissolve.

Excepting the minor effects of varying fall velocity and the presence of ice crystals, the fogs are colloidally stable, and when they dissolve, they do so on account of changes in the large-scale weather situation and not because of internal colloidal instability.

Observational Data.

With the aid of a special microscopic technique developed by Houghton and Radford, the particle size distributions of numerous fogs have been determined (10). A typical curve is reproduced in Fig. 2, which shows how the total

* For a more detailed discussion of colloidal instability see Schmauss und Wigand (6), Bergeron (7), Findeisen (8) and Petterssen (9).

water content is distributed amongst the various drop sizes. It will be noted that the drop diameters range from about 10 to about 100 microns. In radiation fogs the drops are often somewhat smaller than is indicated by Fig. 2, which represents a sea fog. Fogs occurring near large centres of population tend to be composed of small drops, and they are also admixed with considerable quantities of smoke and dust so that such fogs do not usually feel clammy.

The number of drops in a unit volume of foggy air is determined from the size distribution data and the liquid water content. In a dense fog the liquid water content seldom exceeds 0.3 cc./m.^{3}. In a large particle sea fog this corresponds to from 5 to 10 drops per cc. There are probably many more drops per cc. in some city fogs, but no good experimental data are available.

Whereas the theory predicted that a fog would be composed of drops of rather uniform size, the measurements outlined above show that a moderately wide range of sizes is commonly present. This may be due to the fact that a considerable number of relatively large nuclei are present so that the growth of the drops does not proceed far enough to cause size equalisation. It appears more probable, however, that coalescence, particularly that due to the varying rates of fall of the drops, modifies the original rather uniform distribution to produce larger drops.

Transmission of Light through Fog.

It was commonly believed for some time that light of long wave length (red and infra-red) would penetrate fog more readily than the shorter wave lengths. This supposition was based on the formula developed by Lord Rayleigh for the transmission of light through a suspension of particles of a diameter small compared with the wave length of the light. This formula showed that the scattering coefficient was inversely proportional to the fourth power of the wave length. However, since fog drops are large compared with the wave length of visible and near infra-red light, this formula does not apply. For the case of particles which are of the same order of magnitude as the wave length, or larger, the transmission of light over a path z cm. in length is (11)

$$\text{Transmission} = e^{-\pi n r^2 K z} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where n = number of particles per cubic centimetre, r = particle radius in cm., K = a function of r/τ and τ = wave length. For r/τ greater than about five, $K \approx 1$ and the exponent reduces to the total projected area of the drops. Thus in a typical fog with an average drop radius of 20 microns, the transmission is the same for all wave lengths less than about 4 microns. The transmission would not become appreciably higher until the wave length was greater than 40 microns. In this far infra-red region water vapour and some of the other atmospheric gases absorb strongly, so that even though the scattering were reduced, the total transmitted energy would probably be smaller. It may therefore be concluded that there is no region of the radiant energy spectrum which will penetrate fog better than visible light. This result has been confirmed by direct measurements.

Koschmieder (12) has shown that the visibility, or more properly the visual range, is a function only of the scattering coefficient if the observed object is essentially black, is seen against the horizon sky and the sky is uniformly overcast. These conditions are generally satisfied in the case of a fog of considerable depth. The expression for the visual range in fog is

$$V = \frac{\ln \epsilon}{\pi n r^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where V is the visual range in cm., n and r are the same as in Eq. (2) and ϵ is the threshold of contrast, or the ratio of the difference in brightness between the background and the object to the brightness of the background. For most observers the value of ϵ is from 0.01 to 0.02, although in dense fogs it has been found to be as high as 0.06 (Houghton (13)). Eq. (3) may also be written :—

$$V = \frac{Cr}{w} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where C is a numerical constant, and w is the liquid water contained in a unit volume of foggy air. The visual range in a sea fog having a size distribution similar to Fig. 2 and containing 0.3 cc. of liquid water per cubic metre would be about 200 metres. Eq. (4) shows that, for a given liquid water content, the visual range is directly proportional to the average particle radius. Thus, the visual range in small particle fogs, such as radiation and city fogs, may often be very short as compared with a sea fog of the same water content.

Artificial Dissipation of Fog.

Although many unsuccessful attempts to dispel fog have been made, the potential utility of a practical method is great enough to justify a brief discussion of the problem. In general, fog may be dispelled either by the evaporation of the drops or by physically removing the drops from the air. The requirements for the evaporation of the fog drops may be readily evaluated. To evaporate the drops, it is necessary to supply the latent heat of evaporation and also to reduce the relative humidity of the air (as by heating it) so that the additional water vapour can be accommodated. In order to insure a reasonable rate of evaporation, it is usually desirable to reduce the relative humidity by an amount which is considerably larger than the minimum set by the liquid water content of the fog. A reasonable value for the desired relative humidity is 90 per cent. If the initial air temperature were 20°C. and the liquid water content were 0.2 g./m.^{3}, the total heat required to dissipate the fog would be 520 cal./m.^{3}, of which only one-fifth would be used to evaporate the fog drops, the remainder being required to reduce the relative humidity to 90 per cent. Since a certain amount of wind is usually present, fog must be dissipated continuously to maintain a clearing of suitable size. Assuming average fog conditions, Houghton and Radford (14) found that the equivalent of 5,000 kw. would have to be supplied continuously to maintain a cleared volume approximately 40 m. wide by 10 m. high by 600 metres long in the direction of the wind. If this power could be supplied by burning oil, the cost would not be excessive, but the computations assume a uniform distribution of heat, and this would be extremely difficult to arrange for. In any event, it is apparent that it would be impractical to clear large fog-bound areas such as harbours, airports, etc.

The evaporative dissipation of fog may also be accomplished if the relative humidity is reduced by allowing finely divided hygroscopic particles to fall through it. This method has been worked out in detail by Houghton and Radford (14), and a number of successful full-scale demonstrations have been made. A clearing of the size suggested above ($40 \times 10 \times 600$ m.) was maintained in dense fogs with wind velocities as high as 16 m.p.h. by spraying 85 gallons of a saturated aqueous solution of calcium chloride per minute.

Any field of force which would cause the fog drops to coalesce into drops large enough to fall rapidly in the gravitational field, would represent an ideal means for the dispersal of fog. An intense sound field appears to be the only possibility in this direction, but computations indicate that it would not be practical in natural fog, although it has been used to precipitate aerosols such as smoke on a laboratory scale.

The fog may be precipitated by allowing a sufficient number of electrically charged (or uncharged) particles to fall through it. The falling particles collide with the fog drops and carry them to the ground. This method has been tried, using charged sand, with relatively unsatisfactory results. It is also possible to precipitate fog by passing it through a Cottrell-type electrostatic precipitator or through a baffle-like arrangement of fixed surfaces, but both of these methods require expensive and cumbersome apparatus.

Many other fog dissipation methods have been suggested, but all of the feasible ones are modifications of one of those mentioned above, and their relative merit can be judged in the same manner.

Part II.

Meteorological Conditions for the Formation of Fog.

For practical purposes fog is defined as a cloud that envelops the observer and reduces the horizontal range of visibility to 1,000 metres or less. If, under similar circumstances, the horizontal range of visibility exceeds 1,000 metres, the phenomenon is called *mist*.* Since most fogs are formed through cooling, it follows that the air must be cooled sufficiently below its original dew-point to cause so much water to condense that the visibility is reduced below the required limit.

Since condensation nuclei are present in the atmosphere in abundant amounts, condensation will commence when the air is close to the saturation point. Non-saturated air may become saturated in three different ways, viz., (*a*) by evaporating water into the air, (*b*) by mixing between horizontally and vertically adjacent air masses; (*c*) by cooling. In order to obtain a fog, it is necessary that these processes should take place at the earth's surface.

Evaporation.

The evaporation of water, either from the earth's surface or from falling rain, is proportional to the factor

$$(E_w - e)$$

where E_w is the saturation vapour pressure corresponding to the temperature of the liquid water, and e is the actual water vapour pressure of the air. Let E denote the saturation water vapour pressure of the air. The evaporation of water will continue until

$$E_w = e$$

If the temperature of the air is higher than that of the liquid water, the balance will be reached when

$$E > e = E_w$$

and no condensation will result.

If the temperature of the air equals that of the liquid water, balance is attained when

$$E = e = E_w$$

The air becomes saturated, but there is no superfluous water available to produce a fog.

However, when the temperature of the water is higher than that of the air, evaporation will continue until $E_w = e$, in which case

$$E < e = E_w$$

If there were no condensation nuclei, the air would become supersaturated, but since condensation nuclei are always present, the superfluous water will condense. Thus, if the temperature of the water is sufficiently higher than that of the air, the condensed water in the air suffices to produce a fog. Such conditions occur when rain from warm air aloft falls through cold air at the ground (*i.e.*, frontal fog), and when cold air streams over warm water surface (*i.e.*, Arctic sea smoke or steam fog).

Frontal Fog.

Fig. 3*a* shows a cross-section through a frontal surface. If the air above the frontal surface is considerably warmer than the air below, evaporation from the falling rain may cause a fog to form close to the front (Fig. 3*b*). Farther away from the front (Fig. 3*c*), the falling rain would be colder than the air at the earth's surface, and no fog can form because of evaporation of falling rain. However, in this case a stratus layer will form under the frontal surface.

* Definition adopted by the International Meteorological Organisation, 1929.

The fogs that form under such conditions will be arranged as a narrow band in the cold air along the front at the ground. They are therefore called frontal fogs.

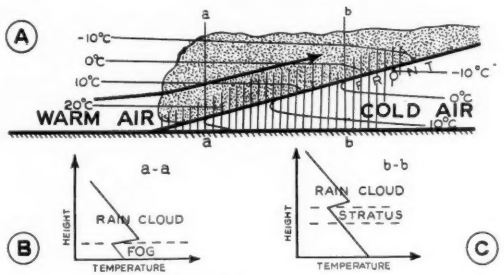

FIG. 3.

A—Cross section through a frontal surface with rain from warm air aloft falling through colder air below. B—Temperature-height curve close to the front. Fog may form because of evaporation close to the front, while stratus may form under the frontal surface at greater distance from the front.

The formation of frontal fogs is counteracted by the turbulent transfer of heat and moisture along the vertical. Only when the temperature of the falling rain is much higher than that of the air at the ground will frontal fogs form. Frontal fogs, therefore, occur almost exclusively in connection with well developed fronts.

STEAM FOG.

Fogs are sometimes observed when cold air streams over a water surface the temperature of which is very much higher than the air temperature. These fogs are known as *Steam Fogs* or *Arctic Sea Smoke*. In such cases $E_w > E$, and if the temperature contrast is large enough, the evaporation is so intense that steam pours forth from the surface and fills the air with fog. Steam fogs are frequently observed in arctic regions in winter when extremely cold air streams over open water. Since the air then is heated from below, it tends to become unstable, and vertical currents will set in and tend to prevent the steam from accumulating near the sea surface. However, when a temperature inversion is present at some short distance above the sea, the whole layer under the inversion may be filled with a dense fog.

Both the frontal fogs and the steam fogs are caused by the same physical process, namely, evaporation of warm water into cold air.

HORIZONTAL MIXING.

The wind is never a steady current. Turbulent eddies form, and as they move from one place to another, they carry moisture, heat, etc., with them.

The mixing that occurs between horizontally adjacent air masses may be assumed to take place at constant atmospheric pressure. Let M_1, T_1 and e_1 denote the total mass, the absolute temperature and the partial pressure of the aqueous vapour in the first component of the mixture, and let similar variables with subscript 2 represent the second component. Let T and e represent the temperature and the vapour pressure in the mixture after complete mixing. The following formulas then hold:—

$$T = \frac{M_1 T_1 + M_2 T_2}{M_1 + M_2}$$

$$e = \frac{M_1 e_1 + M_2 e_2}{M_1 + M_2}$$

The saturation vapour pressure of air is a function of temperature as shown in Fig. 4. Let A and B in Fig. 4 represent the physical conditions of the two components. The point representing the conditions after complete mixing would be found somewhere on the straight line between A and B. It will then be seen that two different air masses of widely different temperatures, neither of which are saturated might become saturated, or supersaturated, after complete mixing.

In the absence of condensation nuclei, the point C would fall to the left of the saturation curve, thus indicating supersaturation. However, since condensation nuclei are always present in abundant amounts, the superfluous water would condense.

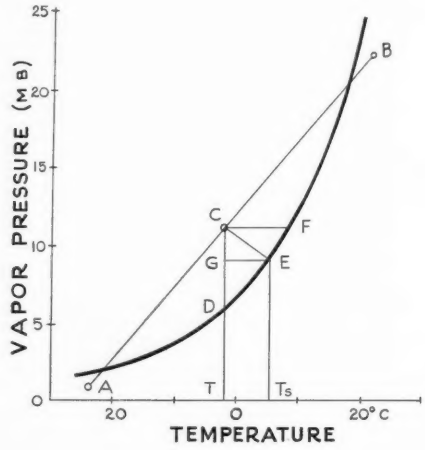

FIG. 4.

When condensation occurs the latent heat of vaporisation is liberated and the air is heated to a certain extent, which, again, tends to reduce the amount of condensed water. Without condensation the point C would have the temperature T and it would be supersaturated by the amount CD. With condensation the temperature would rise from T to T_s and the air would be saturated. The conditions of the mixture would then be represented by the point E and the superfluous water, represented by the line CG, would condense. The actual amount of condensed water can be computed from the Clausius-Clapeyron equation (15), and it has been shown by Petterssen (16) that the amount of condensed water that results from horizontal mixing and such temperature contrasts as occur in the atmosphere is altogether insufficient to produce a fog. Moreover, since horizontal mixing is always accompanied by vertical mixing, it is necessary to consider its effect on the distribution of temperature and moisture.

VERTICAL MIXING.

In this case the pressure is not constant on the individual particles, and it is necessary to consider the adiabatic changes.

The eddy flux of heat in non-saturated air across a horizontal unit area per unit time is expressed by

$$F_1 = -K_1 c_p \rho \, (\gamma_d - \gamma)$$

Here K_1 is the coefficient of eddy transfer of heat, c_p is the specific heat of air at constant pressure, ρ the density of the air, γ_d and γ are, respectively, the dry adiabatic and the actual lapse rate of temperature in the air column.

In a similar manner, the eddy flux of specific humidity (q) is expressed by

$$F_2 = -K_2 \frac{\partial q}{\partial z}$$

where K_2 is the coefficient for eddy transfer of specific humidity.

Suppose now that we stir a layer of air. Heat would then be transported along the vertical until the lapse rate becomes equal to the dry-adiabatic rate, and moisture would be transported along the vertical until the specific humidity is constant with elevation. Furthermore, if no heat and moisture are added to or withdrawn from the air, the contents of heat and moisture must be the same in the initial and in the final state. Let θ denote the potential temperature. The following conditions then characterise the result of complete vertical mixing :—

$$\frac{\partial \theta}{\partial z} = 0 \text{ and } \frac{\partial q}{\partial z} = 0$$

where θ = the mean potential temperature, and q = the mean specific humidity in the air column at the initial moment.

From the above conditions and the Clausius-Clapeyron equation, it follows that the redistribution of heat and moisture would be such that the lower portion of the air column becomes relatively dryer, and the upper portion relatively moister than they were initially. This means that vertical mixing can cause condensation only in the *upper portion of the mixed layer.*

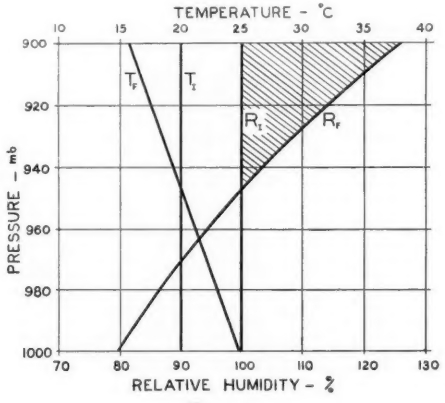

FIG. 5.

T_I and R_I represent the initial distribution of temperature and relative humidity. T_F and R_F represent the final distribution after complete vertical mixing.

A typical example is shown in Fig. 5. Initially the temperature is constant along the vertical and the air is saturated throughout. After complete stirring, the relative humidity has decreased in the lower portion and increased in the upper portion of the mixed layer. In the absence of condensation nuclei, the air in the upper portion of the layer would be supersaturated. However, since condensation nuclei are always present in sufficient amounts, the superfluous water will condense above the level where the relative humidity is 100 per cent. This level may then be called *the mixing condensation level.*

The turbulence set up by the roughness of the ground and the shearing stresses within the friction layer has a marked tendency to prevent fogs from forming and to dissolve fogs that form under adverse conditions.

It was shown in the foregoing paragraph that horizontal mixing may cause only insignificant amounts of condensation even under the most favourable conditions. Since horizontal and vertical mixing operate together, and since the effect of the latter is so much greater than that of the former, it follows that mixing cannot form fogs; in fact, mixing is one of the most potent fog-dissolving agencies.

The turbulent mixing is most intense within the layer directly influenced by the roughness of the ground. This layer is about 2,000-4,000 ft. deep. Therefore, in the upper portion of this layer condensation phenomena are fairly frequent, and their frequency decreases rapidly downward. Thus, turbulence has a tendency to create a cloudless space near the earth's surface.

Cooling.

By far the most frequent and most effective cause of fog formation is cooling of the air while it is in contact with the underlying surface. This cooling may be due to several causes. From the first law of thermodynamics we obtain for the temperature variation:—

$$\frac{dT}{dt} = \frac{1}{c_p}\frac{dQ}{dt} + \frac{1}{c_p}\alpha\frac{dp}{dt} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Here dQ/dt denotes the heat added to, or withdrawn from, a unit mass of air per unit time, c_p = specific heat of air at constant pressure, α = specific volume and p = atmospheric pressure.

Let V_x, V_y and V_z denote the wind components along the co-ordinate axes, with the z axes along the vertical. Then

$$\frac{dp}{dt} = \frac{\partial p}{\partial t} + \frac{\partial p}{\partial x}V_x + \frac{\partial p}{\partial y}V_y + \frac{\partial p}{\partial z}V_z \quad . \quad . \quad . \quad . \quad (6)$$

which substituted in the above equation gives

$$\frac{dT}{dt} = \frac{1}{c_p}\frac{dQ}{dt} + \frac{\alpha}{c_p}\frac{\partial p}{\partial t} + \frac{\alpha}{c_p}\left(\frac{\partial p}{\partial x}V_x + \frac{\partial p}{\partial y}V_y\right) + \frac{\alpha}{c_p}\frac{\partial p}{\partial z}V_z \quad . \quad . \quad (7)$$

This equation shows that there are four factors that control the temperature changes of the moving air, namely:—

(*a*) The non-adiabatic heating or cooling represented by the term containing dQ/dt. This term is always important and may amount to 1° or 2°C. per hour.

(*b*) The adiabatic heating or cooling represented by the term containing $\partial p/\partial t$ (the local pressure variation). The air would be cooled when the barometer falls, and it would be heated when the barometer rises. This term, however, is very small and will not exceed 0.1°C. per hour. It may therefore be neglected in the discussion of the fog producing processes.*

(*c*) The adiabatic heating or cooling due to the flux of air across the isobars. When the air moves horizontally from high to low pressure, it will expand and cool, but this effect is exceedingly small (about 0.01°C. per hour), and may be disregarded.

(*d*) The adiabatic heating or cooling caused by vertical motion, as represented by the term containing V_z. This term vanishes over level ground, because then $V_z = 0$. However, when the air moves up or down a mountain slope, the term becomes important and may amount to several degrees Centigrade per hour.

Accordingly we may write

$$\frac{dT}{dt} = \frac{1}{c_p}\frac{dQ}{dt} + \frac{\alpha}{c_p}V_z\frac{\partial p}{\partial z} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and fogs may form as a result of non-adiabatic cooling, or adiabatic cooling due to upslope motion. The non-adiabatic cooling may be due to two causes, viz., the radiative cooling of the underlying surface, and the advective cooling that results when warm air streams over a colder surface. We may therefore speak of *radiation fogs*, *advection fogs* and *upslope fogs*.

* For a more complete discussion of the order of magnitude of the fog producing processes, see Petterssen (9, 16).

Since the mechanism of the formation of these types of fogs has been discussed in detail elsewhere,* a few comments will suffice to show the relative importance of the types of fog caused by cooling.

Advection Fog.

The rate of cooling of the travelling air depends on the difference in temperature between the air and the underlying surface, which again depends on the speed with which the air streams cross the isotherms of the underlying surface. In extreme cases, the cooling may amount to 2°C. per hour. As high wind velocities are accompanied by intense turbulence and vertical mixing, it follows from the section on " Vertical Mixing " that advection fogs cannot readily form in strong winds. On the other hand, very slight winds are also unfavourable for the production of advection fogs, because the transport of air across the isotherms of the underlying surface is then so slight that temperature equilibrium is reached. As a result, it is found that advection fogs occur most frequently with wind velocities from 5 to 15 m.p.h. Advection fogs with wind velocity above 30 m.p.h. are exceedingly rare.

Advection fogs occur quite frequently over land in winter when air from the oceans invades the cold continents. Since the radiative temperature changes are relatively large over continents, most land fogs are caused by the combined influence of advective and radiative cooling.

At sea, the diurnal variation of the temperature of the underlying surface is exceedingly small (usually less than 0.5°C.). The sea fogs are therefore either advection fogs or frontal fogs. The sea fogs occur most frequently over the cold ocean currents (*e.g.*, the Labrador Current) during invasions of warm air. Sea fogs occur quite frequently along the Gulf coast in winter on account of the cold water transported southward by the Mississippi. The summer fog along the California coast (17) is, to a certain extent, caused by advection of warm air over the cold upwelling water along the coast.

Radiation Fog.

The influence of the radiative cooling of land areas on the air temperature is of the order of magnitude of 1°C. per hour, and is therefore important. However, since turbulence normally transports heat downward toward the surface, the radiative cooling of the surface is counteracted by the eddy flux of heat. Normally, the specific humidity decreases with elevation. The eddy flux of humidity is then directed upward. Moreover, when the sky is overcast, the counter-radiation from the sky is considerable, and reduces the cooling of the underlying surface. Thus, the conditions favourable for radiation fogs to form are: Cloudless sky, calm or almost still air, and specific humidity increasing along the vertical.

The above conditions occur most frequently in continental anticyclones in the colder part of the year, or in any uniform pressure distribution where there is enough subsidence in the upper air to dissolve the clouds. As high relative humidity is an important factor, radiation fogs develop most frequently in air of maritime origin when it becomes stagnant over cold continents. As mentioned above, radiation fogs do not occur at sea.

Upslope Fog.

The last term in Eq. (8) (see section on " Cooling ") vanishes over level ground, but when the air blows up a slope, it cools at a rate of 1°C. per 100 metre ascent. Thus, when the ascending velocity is considerable, the adiabatic term will become larger than the non-adiabatic term, and a fog may form because of the adiabatic cooling. Such fogs, which are called *upslope fogs*, form quite frequently on the eastern slope of the Rocky Mountains when warm and moist air from the Gulf streams up the slope.

* Petterssen (16) and Willett (19).

The formation of upslope fogs is counteracted by turbulence, as is the formation of all kinds of fogs. Moreover, in order to obtain fog through upslope motion, it is necessary that the air, when saturated, be stably stratified, because otherwise convectional currents would develop. Therefore, upslope fogs can form only when the air is convectively stable before the ascent commences. Consequently, upslope fogs are not possible when the potential wetbulb temperature decreases with elevation. When the said temperature increases with elevation, upslope fogs may, or may not form, depending on the intensity of turbulence.

Diurnal Variation.

All types of fog have a tendency to dissipate through heating; there is therefore a marked diurnal variation in the frequency of fogs, with a maximum in the early morning hours and a minimum in the afternoon. Naturally, a shallow fog burns off more readily than a deep fog. Since upslope fogs and advection fogs are usually deeper than radiation fogs, the latter type has a more distinct diurnal variation than the former.

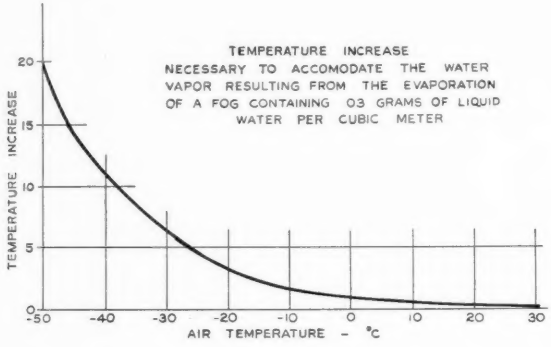

Fig. 6.

Other conditions being equal, the diurnal variation is the more pronounced the higher the temperature. According to Houghton, a dense fog contains about 0.3 gram of liquid water per cubic metre. In order to dissipate the fog, this water must be evaporated, and in addition, the air temperature must be increased so much that this additional amount of water vapour can be accommodated in the air. It follows then from Fig. 4 that only a slight increase in air temperature suffices to accommodate the fog water when the air temperature is high, but a considerable amount of temperature increase is required when the air temperature is low. A simple computation gives the values contained in Fig. 6. Furthermore, it is well known that the diurnal variation in temperature is large when the air temperature is high, and it is small when the air temperature is low. For both these reasons, fogs that occur at high temperatures (in the warm season) will have a distinct tendency to burn off in the early morning, while fogs that occur at low temperatures (in the cold season) do not readily dissolve because of the diurnal heating. Fogs that occur in tropical climates, therefore, have a very regular daily rhythm, while those occurring in arctic and polar continental regions in winter have only a slight diurnal variation.

Fog Over Snow-Covered Ground.

It was mentioned in the section on "Colloidal Stability" that a mixture of water droplets and ice crystals is colloidally unstable when the air temperature is below freezing. Since a considerable portion of the Northern Hemisphere is

covered by snow for part of the year, it is of interest to investigate the behaviour of fog over snow-covered ground.

In Fig. 7, the curve ΔE represents the difference in saturation pressure over water and over ice as a function of air temperature. The curve R represents the relative humidity when the vapour pressure of the air equals the saturation pressure over ice.

When the air over a snow-covered surface is cooled to such an extent that its relative humidity increases to the value indicated by R in Fig. 7, water vapour is sublimated on the snowy surface. As this continues, the air obtains a minimum of specific humidity at the surface. The eddy flux of moisture will then be directed downward, and the air column gives off moisture to the snow.

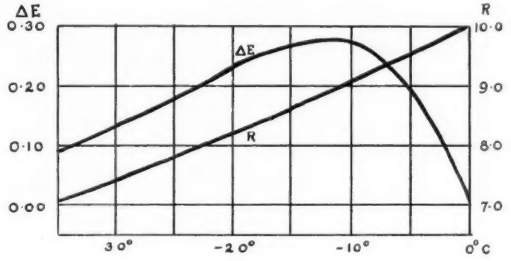

FIG. 7.

Difference in saturation pressure over water and over ice (curve ΔE); and relative humidity (curve R) of air which is saturated over ice.

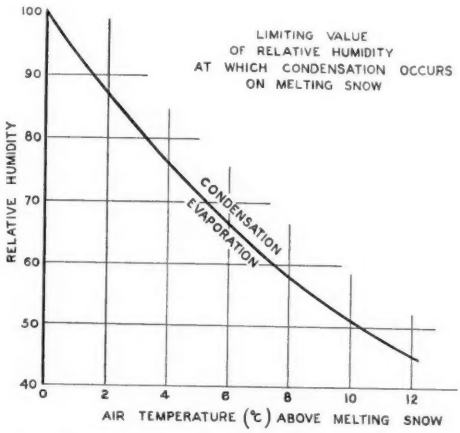

FIG. 8.

When the air temperature is slightly below freezing, ΔE is small, and a fog may form. The fog must then give off moisture to the snowy surface, and the fog can be maintained only through further cooling. As the air temperature decreases to -10 to -15°C., ΔE increases to its maximum value, and it becomes increasingly difficult for a fog to form; and a fog that is already formed will have a marked tendency to dissolve.

This applies to temperatures below freezing. The conditions are, however, quite different when the air temperature is above freezing. The snow is then

melting, and the air that is in direct contact with the melting snow is close to o°C. and its relative humidity is 100 per cent. The eddy flux of heat will now be directed toward the snowy surface, and the heat that the air gives off is used to melt snow, with the result that the temperature of the snow stays constant at o°C.

If the specific humidity of the air decreases with elevation, the eddy flux of moisture carries humidity away from the surface, and the snow evaporates. However, if the specific humidity increases with elevation (which is the normal condition above melting snow) the eddy flux of humidity would be toward the snowy surface, and condensation would take place on the snow. Sverdrup (18) found that the latent heat thus liberated contributes materially to the melting of the snow in spring.

This implies that condensation occurs on the melting snow whenever the specific humidity increases with elevation. A simple computation shows that water is condensed on the snow whenever the *relative humidity* at some small distance above the melting snow exceeds the limiting values shown in Fig. 8, the limiting values being a function of the air temperature at some small distance above the snow. Thus, for example, if the air temperature were 4°C., condensation would occur on the snow as soon as the relative humidity exceeds 77 per cent. The air would, therefore, give off moisture to the melting snow long before it approaches the saturation point.

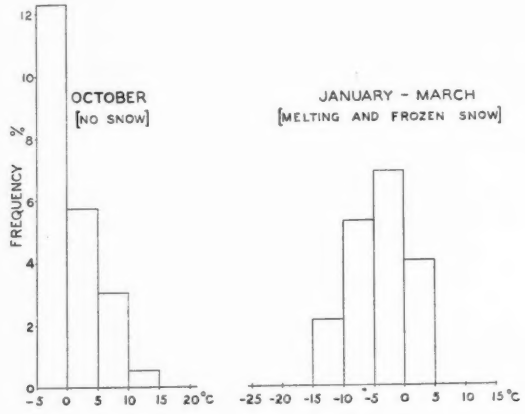

FIG. 9.

Fog frequencies. Oslo, Norway.

In order for a fog to form, or maintain itself over melting snow, it is necessary that the air be cooled so rapidly that the downward eddy flux of moisture is over-compensated by the cooling. This can occur only through advection of warmer air over the snow, which is a frequent phenomenon over snow-covered continents in spring, and in the arctic and antarctic in summer, but the fogs thus formed must constantly give off part of their water content to the snow underneath, and they can then be maintained only if there is sufficient advection of warmer air which is cooled with sufficient speed. As a result, fogs over melting snow with air temperatures much above freezing are extremely rare.

To sum up, we may say that melting snow has a marked tendency to dissipate fogs. This dissipating influence increases the higher the air temperature is above o°C. As the air temperature decreases to o°C., this dissipating influence

vanishes; but when the air temperature falls below freezing, another dissipating influence, due to the depression of the saturation pressure over ice (see Fig. 7), commences and increases in intensity until the air temperature reaches $-10°$ to $-15°$C., where it has a maximum. It follows then that a water fog is in a stable state over snow only when the air temperature is not far removed from 0°C.

The above conclusions are corroborated by observational evidence. An example is shown in Fig. 9. Let f denote the frequency of occurrence of fog within temperature intervals of 5°C., and let F be the frequency of air temperatures within the same intervals. Fig. 9 then shows the value of $100\,f/F$ for any observed temperature in Oslo. It should be noted that October is a snowless month, January and February are snow covered, with temperatures mostly below freezing, and March is characterised by melting snow. It will be seen from Fig. 9 that in October the fog frequency increases steadily with decreasing air temperature as one would expect over snowless ground. When snow is present on the ground, the frequency curve has a totally different trend. The maximum fog frequency does not occur at the lowest temperature, but when the air temperature is close to freezing. That the maximum of fog frequency falls in the interval 0 to $-5°$C. and not in the interval 0 to $+5°$C. seems to show that the dissipating influence due to the depression of the saturation pressure over ice is less intense than that due to the deposition of water on melting snow.

Frequency curves similar to Fig. 9 for stations in North Siberia show that the fog frequency over snow increases when the air temperature sinks below $-35°$C. This is due to the fact that the fogs that occur at such low temperatures are ice crystal fogs, and these are in equilibrium with respect to the underlying surface.

Classification of Fog.

Summing up the foregoing discussion, the fogs may be classified according to the intensity of the process which constitutes the principal cause of their formation. A classification based on this principle is given in Table II. A summary of the fog dissipating agencies is given in the right-hand portion of the table.

Table II.

Classification of Fog.

Fog Producing Processes	Fog Dissipating Processes
1. Evaporation from:	1. Sublimation or condensation on:
1. Rain which is warmer than the air (rain area fog, or frontal fog).	1. Snow with air temperature below 0°C. (excepting ice crystal fogs).
2. Water surface which is warmer than the air (steam fog).	2. Snow with air temperature above 0°C. (melting snow).
2. Cooling due to:	2. Heating due to:
3. Adiabatic upslope motion (upslope fog).	3. Adiabatic downslope motion.
4. Flux of air across the isobars toward lower pressure (isobaric fog; effect negligible).	4. Flux of air across the isobars toward higher pressure (effect negligible).
5. Falling pressure (isallobaris fog; unimportant).	5. Rising pressure (unimportant).
6. Radiation from the underlying surface (radiation fog).	6. Radiation absorbed by the fog or by the underlying surface.
7. Advection of warmer air over a colder surface (advection fog).	7. Advection of colder air over a warmer surface.
3. Mixing:	3. Mixing:
8. Horizontal mixing (unimportant by itself and strongly counteracted by vertical mixing).	8. Vertical mixing (important in dissipating of fogs and producing stratus).

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Technical Memorandum No. 939.

THE TORSION OF BOX BEAMS WITH ONE SIDE LACKING.*

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The torsion of box beams of rectangular section, the edges of which are strengthened by flanges, and of which one side is lacking, is analysed by the energy method. The torsional stresses are generally taken up by the bending of the two parallel walls, the rigidity of which is augmented by the third wall. The result was checked experimentally on duralumin and plywood boxes. The torsion recorded was 10 to 30 per cent. less than that given by the calculation, owing to self-stiffening.

I. Introduction.

Box beams (rectangular) lacking one side, with or without bulkheads, find frequent use in aeroplane design as, for instance, on the wing near fuel tanks, or bomb racks, or the landing gear, or even in the fuselage in the vicinity of a wide door, or of the load compartment for dropable loads (bombs, provisions), or incidental to armament installation. Shell constructions of rectangular, rounded-off section, as customary on wings and fuselages near openings extending to an inside wall, or in any case of considerable width, can also be approximately treated as such.

Section II explains the unsuitability of Bredt's method. The analysis is made according to Minelli's procedure.

Section III describes an experimental procedure for the exact derivation of the values of shear modulus G. The experimental solution of G and Young's modulus E of the employed material is followed subsequently by a torsion test and a torsion analysis of thin-walled prismatic beams of rectangular section with one side lacking. The materials are duralumin and plywood. The analytical data are discussed and compared with the test data.

II. Theoretical Analysis of Torsion.

Bredt's theory of torsion of hollow cylinders and thin-walled prisms states that the torsional stiffness of a body of this type is zero when a part lying between two generatrices is lacking or, more simply expressed, when the body along a generatrice is cut up. It is sufficient to check Bredt's formula

$$B=\frac{4\,GS^2}{\int dc/s}$$

If $s=0$, for no matter how small the region, then $B=0$.

Experience, on the other hand, shows that it is possible to maintain a certain, not negligible, torsional stiffness for hollow, thin-walled prisms, which are partitioned and open. (The partitioning corresponds to that considered in Bredt's theory.) It only stipulates the prisms to be built in at one end or both—this

* "Berechnung der Verdrehung kastenförmiger Träger, denen eine Wand fehlt." Luftfahrtforschung, Vol. 16, No. 8, August 20, 1939, pp. 403-411. ("Il calcolo torsionale delle travi a cassone mancanti di una parete.")

case is technically little probable—in such a way as to preclude axial warping of the end section.

Torsional stiffness can be markedly increased by flanges running along the edges of the hollow, open prism. In consequence, the torsional stress involved does not correspond to the classical St. Venant-Bredt stress, but rather to one under which the particular hollow body, which the external force tries to twist, and actually twists, not merely reacts with shearing stresses but also with normal stresses. In other words, rather than a true *hollow body*, it represents a *system* of beams joined along the edges, each of which is stressed separately in shear and bending.

With a type of fixity not prohibiting axial warping of the end section, the hollow body could have no torsional stiffness differing from zero. If the upright walls were joined at the point of fixity with a cylindrical hinge with vertical axis, and the horizontal wall with a cylindrical hinge with vertical axis, thus permitting the built-in section to warp at will, the torsional stiffness would be zero. Hence, it is assumed that the restraint is actually as previously indicated, so that the problem becomes that of torsion of an open, thin-walled prism with flanges and partitions, as illustrated in Fig. 1.

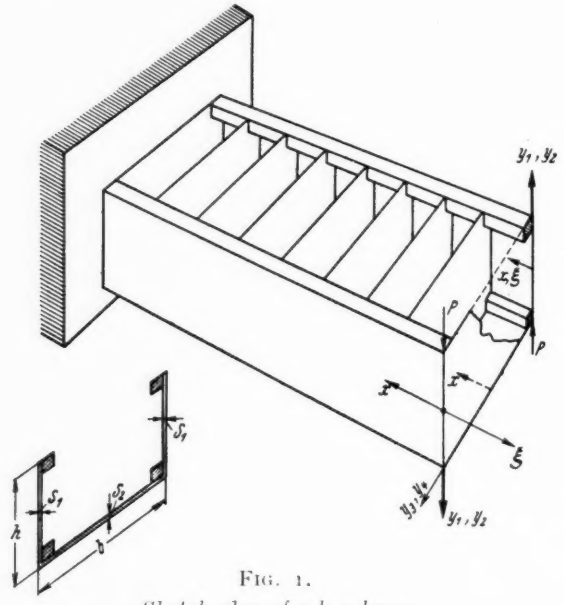


FIG. 1.

Sketch plan of a box beam.

The torque is transmitted by means of two vertical forces P of equal magnitude and opposite direction and applied at the vertical walls in the end section. What are the elementary form changes of which the state of the total form change consists?

The two vertical walls are strained by antisymmetrical bending moments of equal and opposite magnitude. Let y_1 be the bending ordinate, and y_2 the shear ordinate of a vertical wall.

The tendency of the left or right wall to deflect upward or downward is counteracted by the liaison of the vertical walls with the horizontal wall along the edges. Actually the horizontal wall prevents the lower edge of the vertical left wall from becoming shorter and that of the right-hand wall from becoming

longer. The result is a counter-effect on the upright wall facing the horizontal wall along the edge, which produces an axial strain in these walls. It is therefore necessary to take into account a total axial displacement $\xi(x)$ of the sections on the vertical walls, naturally in the opposite direction; that is, toward the negative x axis for the left wall, and toward the positive x axis for the right wall.

The horizontal wall itself receives axial reactions from the vertical walls, of equal magnitude and opposite direction, against which it can react only with the bending y_3 and, if necessary, with the shear y_4. But it is not strained as a whole; *i.e.*, its centre line retains its original length.

The state of deformation is therefore reduced to the five parameters y_1, y_2, ξ, y_3, y_4. Their positive directions are those shown in Fig. 1. As seen, the x axis for each wall was assumed with point of origin in the outside free end. The positive direction points from free end toward the restraint. The strain condition is explored by means of the energy method, which is based on the principle of virtual energy (reference 1). (The notation used in the present report is the same as Minelli's (reference 1).)

Let L denote the strain energy, and U the sum of the scalar products of external forces and displacements of their applied points, then form the difference $L-U$. The principle states that between all strain conditions reconciled with the type of support, the state for which $L-U$ becomes a minimum is the true state. Hence, expressing $L-U$ in relation to the form changes and defining these to the satisfaction of the support conditions and the minimum condition for $L-U$ gives the true state of strain. For the case in point, it is:—

$$U=P\{y_1(0)+y_2(0)\}=-\int_0^l P(y'_1+y'_2)\,dx$$

Now L is to be expressed.

Let J_v and J_o, respectively, denote the moment of inertia of one vertical or the horizontal wall, Ω the cross-sectional area of a vertical wall, s_1 the thickness of a vertical wall of height h, and s_2 of the horizontal wall of height b.

The flanges contained in Ω are assumed equal, and they are also counted in, in J_v. If, instead, the lower flanges are ascribed to the horizontal wall, J_v would have to be given a value which would correspond to the vertical wall without the lower flange, whereby the neutral axis of the wall would be displaced upward. The stress τ along the wall web is assumed uniformly distributed, and hence $\tau=-Gy'_2$ in the vertical walls as well as in the horizontal wall. Then

$$L=\int_0^l\left\{2\tfrac{1}{2}\,EJ_v y''_1{}^2+\frac{EJ_o}{2}y''_3{}^2+2\tfrac{1}{2}\,E\Omega\xi'^2+2\tfrac{1}{2}\,Gs_1hy'_2{}^2+\frac{Gs_2b}{2}y'_4{}^2\right\}dx \qquad (0)$$

and $L-U$ may be expressed with

$$L-U=\int_0^l\left\{EJ_v y''_1{}^2+\frac{EJ_o}{2}y''_3{}^2+E\Omega\xi'^2+Gs_1hy'_2{}^2+\frac{Gs_2b}{2}y'_4{}^2+2P(y'_1+y'_2)\right\}dx \qquad (1)$$

The result is a functional, depending on five functions which must make it a minimum. The equation of continuity between two walls along the edge eliminates one. Owing to the equality of strain along the edge, we have for the two vertical walls:—

$$\xi+\frac{h}{2}y'_1=\frac{b}{2}y'_3$$

from which follows:—

$$y'_3=\left(\frac{2}{b}\xi+\frac{h}{b}y'_1\right) \qquad (2)$$

The substitution of this expression for y_3 in equation (1) reduces the new functional to the four functions y_1, y_2, y_4, ξ, giving

$$L-U=\int_0^l \left\{ EJ_v y''_1{}^2+\frac{EJ_0}{2}\left(\frac{2}{b}\xi'+\frac{h}{b}y''_1\right)^2+E\Omega\xi'^2 \right.$$

$$\left. +Gs_1 h y'_2{}^2+\frac{Gs_2 b}{2}y'_4{}^2+2P(y'_1+y'_2)\right\} dx \quad . \quad . \quad . \quad (3)$$

In the search of the functions y_1, y_2, y_4, ξ, which make this functional a minimum, the following limiting conditions which reflect the geometric constraint at the point fixity, should be observed:—

$$y_1(l)=y_2(l)=y_4(l)=0;\ y'_1(l)=0;\ \xi(l)=0 \quad . \quad . \quad . \quad (4)$$

A variation $\varepsilon\eta$ is applied separately to each of the four functions. Considering the corresponding functional as function $\Phi(\varepsilon)$, we can write:—

$$\left(\frac{\partial\Phi(\varepsilon)}{\partial\varepsilon}\right)_{\varepsilon=0}=0 \quad . \quad . \quad . \quad . \quad . \quad (5)$$

η must naturally comply with the established limiting conditions which y_1, y_2, y_4, ξ themselves satisfy. Equation (5) is the well-known equation of the calculus of variations.

The variation is first applied to y_4.

$$\Phi(\varepsilon)\int_0^l \left\{ EJ_v y''_1{}^2+\frac{EJ_0}{2}\left(\frac{2}{b}\xi'+\frac{h}{b}y''_1\right)^2+E\Omega\xi'^2 \right.$$

$$\left. +Gs_1 h y'_2{}^2+\frac{Gs_2 b}{2}(y'_4+\varepsilon\eta'_4)^2+2P(y'_1+y'_2)\right\} dx \quad . \quad . \quad (5a)$$

Applying equation (5) gives at once:—

$$\left(\frac{\partial\Phi(\varepsilon)}{\partial\varepsilon}\right)_{\varepsilon=0}=\int_0^l Gs_2 b y_4\eta'_4 dx=0 \quad . \quad . \quad . \quad . \quad (5b)$$

or

$$\int_0^l y'_4\eta'_4 dx=0 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Partial integration gives:—

$$\int_0^l y'_4\eta'_4 dx=\left|y'_4\eta_4\right|_0^l-\int_0^l y''_4\eta_4 dx=-y'_4(0)\eta_4(0)-\int_0^l y_4''\eta_4 dx=0 \quad . \quad (6a)$$

This equation is complied with then and then only for any form of the function η_4 when

$$y''_4=0;\ y'_4(0)=0 \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Adding the known geometric condition $y_4(l)=0$ gives y_4 for which

$$y_4(x)=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Returning to the functional while posing $y_4=0$, and applying the variation to y_2 gives

$$\Phi(\varepsilon)=\int_0^l \left\{ EJ_v y''_1{}^2+\frac{EJ_0}{2}\left(\frac{2}{b}\xi'+\frac{h}{b}y''_1\right)^2+E\Omega\xi'^2 \right.$$

$$\left. +Gs_1 h(y'_2+\varepsilon\eta'_2)^2+2P(y'_1+y'_2+\varepsilon\eta'_2)\right\} dx \quad . \quad . \quad . \quad (8a)$$

Equation (5) gives a relation which, divided by 2, has the form

$$\int_0^l (Gs_1 h y'_2\eta'_2+P\eta'_2)\,dx=0 \quad . \quad . \quad . \quad . \quad (9)$$

or

$$\int_0^l \eta'_2 \,(Gs_1 h y'_2 + P)\, dx = 0 \qquad . \quad . \quad . \quad . \quad . \quad (9a)$$

Equation (9*a*) is satisfied for any function η_2 if

$$Gs_1 h_2 y'_2 + P = 0 \qquad . \quad . \quad . \quad . \quad . \quad (10)$$

The integration of equation (10) with regard to equation (4) for y_2, that is, $y_2\,(l) = 0$, gives :—

$$y_2 = \frac{P}{Gs_1 h}(l - x) \qquad . \quad . \quad . \quad . \quad . \quad (11)$$

Applying the variation to ξ gives :—

$$\Phi\,(\epsilon) = \int_0^l \Big\{ EJ_v y''^2_1 + \frac{EJ_0}{2}\Big[\frac{2}{b}\,(\xi' + \epsilon\eta') + \frac{h}{b} y''_1\Big]^2$$

$$+ E\Omega\,(\xi' + \epsilon\eta')^2 + Gs_1 h y_2'^2 + 2\,P\,(y'_1 + y'_2)\Big\}\, dx \qquad . \quad . \quad (11a)$$

The application of equation (5) leaves :—

$$\int_0^l \Big\{ EJ_0 \Big(\frac{2}{b}\xi' + \frac{h}{b} y''_1\Big)\frac{2}{b}\eta' + 2\,E\Omega\xi'\eta' \Big\}\, dx = 0 \qquad . \quad . \quad (12)$$

which, multiplied by $b^2/2$, and the common factor η' placed in brackets, affords

$$\int_0^l \eta' \,\{\,(2\,EJ_0 + E\Omega b^2)\,\xi' + hEJ_0 y''_1\,\}\, dx = 0 \qquad . \quad . \quad . \quad (13)$$

This equation is satisfied for any function η if

$$\xi' = \frac{-hEJ_0}{2\,EJ_0 + E\Omega b^2} y''_1 \qquad . \quad . \quad . \quad . \quad (14)$$

Then the variation is applied to y_1

$$\Phi\,(\epsilon) = \int_0^l \Big\{ EJ_v\,(y''_1 + \epsilon\eta''_1)^2 + \frac{EJ_0}{2}\Big[\frac{2}{b}\xi' + \frac{h}{b}(y''_1 + \epsilon\eta''_1)\Big]^2 + E\Omega\xi'^2$$

$$+ Gs_1 h y'^2_2 + 2\,P\,(y'_1 + \epsilon\eta'_1 + y'_2)\Big\}\, dx \qquad . \quad . \quad . \quad (15)$$

The application of equation (5) gives :—

$$\int_0^l \Big\{ 2\,EJ_v y''_1 \eta''_1 + EJ_0 \Big(\frac{2}{b}\xi' + \frac{h}{b} y''_1\Big)\frac{h}{b}\eta''_1 + 2\,P\eta'_1 \Big\}\, dx = 0 \qquad . \quad (15a)$$

or, rearranged,

$$\int_0^l \Big\{ \Big(2\,EJ_v + \frac{h^2}{b^2} EJ_0\Big) y''_1 \eta''_1 + \frac{2\,h}{b^2} EJ_0 \xi' \eta''_1 + 2\,P\eta'_1 \Big\}\, dx = 0 \qquad . \quad (15b)$$

Partially integrated, the first expression of the integral reads :—

$$\int_0^l y''_1 \eta''_1 dx = \Big| y''_1 \eta'_1 \Big|_0^l - \int_0^l y'''_1 \eta'_1 dx = -\,y''_1\,(0)\,\eta'_1\,(0) - \Big| y'''_1 \eta_1 \Big|_0^l$$

$$+ \int_0^l y_1^{IV} \eta_1 dx = -\,y''_1\,(0)\,\eta'_1\,(0) + y'''_1\,(0)\,\eta_1\,(0) + \int_0^l y_1^{IV} \eta_1 dx \qquad . \quad (16)$$

and the second expression :—

$$\int_0^l \xi' \eta''_1 dx = \left| \xi' \eta'_1 \right|_0^l - \int_0^l \xi'' \eta'_1 dx = -\xi' \ (0)\ \eta'_1\ (0) - \left| \xi'' \eta_1 \right|_0^l$$

$$+ \int_0^l \xi''' \eta_1 dx = -\xi' \ (0)\ \eta'_1\ (0) + \xi''\ (0)\ \eta_1\ (0) + \int_0^l \xi''' \eta_1 dx \quad . \quad . \quad (17)$$

while the third can, as we know, be written as $-2P\eta_1\ (0)$, so that in conjunction with equations (16) and (17), equation (15*a*)

$$\left.\begin{aligned} &-\left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y''_1\ (0)\ \eta'_1\ (0) + (2EJ_v \\ &+ \frac{h^2}{b^2} EJ_0)\ y'''_1\ (0)\ \eta_1\ (0) + \int_0^l \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y_1^{IV} \eta dx \\ &- \frac{2h}{b^2} EJ_0 \xi'\ (0)\ \eta'_1\ (0) + \frac{2h}{b^2} EJ_0 \xi''\ (0)\ \eta_1\ (0) \\ &+ \int_0^l \frac{2h}{b^2} EJ_0 \xi''' \eta_1 dx - 2P\eta_1\ (0) = 0 \end{aligned}\right\} \quad . \quad . \quad (18)$$

The integrals are arranged into a single integral, the expressions with respect to $\eta_1\ (0)$ and $\eta'\ (0)$ being divided into two groups :—

$$\left.\begin{aligned} &-\eta'_1\ (0)\left[\frac{2h}{b^2} EJ_0 \xi'\ (0) + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y''_1\ (0)\right] \\ &+ \eta_1\ (0)\left[\frac{2h}{b^2} EJ_0 \xi''\ (0)\right. \\ &\left. + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y'''_1\ (0) - 2P\right] \\ &+ \int_0^l \eta_1 \left[\frac{2h}{b^2} EJ_0 \xi''' + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y_1^{IV}\right] dx = 0 \end{aligned}\right\} \quad . \quad . \quad (18a)$$

Equation (18*a*) is satisfied only when the following conditions are complied with :—

$$\frac{2h}{b^2} EJ_0 \xi''' + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y_1^{IV} = 0 \quad . \quad . \quad . \quad (19)$$

$$\frac{2h}{b^2} EJ_0 \xi''\ (0) + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y'''_1\ (0) - 2P = 0 \quad . \quad . \quad (20)$$

$$\frac{2h}{b^2} EJ_0 \xi'\ (0) + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y''_1\ (0) = 0 \quad . \quad . \quad . \quad (20a)$$

The result is a differential equation, namely (19), and two limiting conditions (20) and (20*a*).

Integration of equation (19), with due regard to equation (20) gives :—

$$\frac{2h}{b^2} EJ_0 \xi'' + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y'''_1 - 2P = 0 \quad . \quad . \quad (21)$$

and of equation (21) with due regard to equation (20*a*) :—

$$\frac{2h}{b^2} EJ_0 \xi' + \left(2EJ_v + \frac{h^2}{b^2} EJ_0\right) y''_1 - 2Px = 0 . \quad . \quad . \quad (21a)$$

Aside from equation (21*a*), we again write equation (14) obtained from the minimum condition with respect to ξ.

$$\xi' = \frac{-hEJ_o}{2EJ_o + E\Omega b^2} y''_1 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

which, after elimination of ξ' from equations (21*a*) and (14), and minor changes, leaves :—

$$y''_1 = \frac{Px}{EJ_v + h^2/2\,(2/E\Omega + b^2/EJ_o)} \quad . \quad . \quad . \quad . \quad (22)$$

Integration, with allowance for y_1 (equation (4)), gives :—

$$y_1 = \frac{P}{6} \frac{x^3 - 3\,l^2 x + 2\,l^3}{EJ_v + h^2/2\,(2/E\Omega + b^2/EJ_o)} \quad . \quad . \quad . \quad (23)$$

Integration of equation (14) with due regard to equation (4) for ξ and y_1 gives :—

$$\xi = \frac{-hEJ_o}{2EJ_o + E\Omega b^2} y'_1 \quad . \quad . \quad . \quad . \quad . \quad (14a)$$

which, since y_1 is known from equation (23), gives :—

$$\xi = \frac{EJ_o h}{2EJ_v\,(2EJ_o + b^2 E\Omega) + h^2 EJ_o E\Omega} P\,(l^2 - x^2) \quad . \quad . \quad (24)$$

There remains then the solution of y_3. Equations (2) and (14*a*) afford a relation between y'_3 and y'_1 which, with allowance for $y_3\,(l) = y_1\,(l) = 0$ ultimately gives :—

$$y_3 = \frac{bhE\Omega}{2EJ_o + b^2 E\Omega} y_1 \quad . \quad . \quad . \quad . \quad (25)$$

The strain condition is therefore completely defined through $y_1\,(x)$ from equation (23), $y_2\,(x)$ from equation (11), $y_3\,(x)$ from equation (25), $\xi\,(x)$ from equation (24) and because $y_1\,(x) = 0$.

The construction of equation (23) discloses that $y_1\,(x)$, that is, the bending line of a vertical wall, agrees with the bending line of a built-in cantilever beam under load P at the free end, with the inertia moment :—

$$J_v + \frac{h^2}{2\,(2/\Omega + b^2/J_o)} = J_v \left(1 + \frac{h^2}{2\,J_v\,(2/\Omega + b^2/J_o)}\right) \quad . \quad . \quad (23a)$$

while the natural inertia moment of the wall section is J_v only. Formula (23*a*) definitely expresses the effect of the presence of the horizontal wall on the bending stiffness of the vertical walls.

The shear strains on a vertical wall are equal to those of a beam of the same size, built in, cantilevered, and loaded in the same manner.

The moments in the vertical walls, positive in the sense of the moment due to P, are in any section

$$M_v = EJ_v y''_1 = \frac{Px}{1 + [h^2/2\,EJ_v\,(2/E\Omega + b^2/EJ_o)]} \quad . \quad . \quad (26)$$

The moment is, as seen, given by the product of $P \times x$ the moment existing in a vertical wall which is no longer connected with the horizontal wall, and a correction factor < 1, expressing the reduction in stress in a vertical wall by virtue of the attachment with the horizontal wall.

Equation (24) gives the specific strain ξ' :—

$$\xi' = \frac{-2EJ_o h}{2EJ_v\,(2EJ_o + b^2 E\Omega) + h^2 EJ_o E\Omega} Px \quad . \quad . \quad . \quad (27)$$

The total normal stresses (positive, if tensile) in the upper and lower edges of the left vertical wall is given by the formula :—

$$\sigma_{\substack{\text{upper}\\\text{lower}}} = -E\xi' \pm \frac{M}{J_v}\frac{h}{2} = -E\xi' \pm \frac{EJ_v y''_1}{J_v}\frac{h}{2} = E\left(-\xi' \pm \frac{h}{2} y''_1\right). \quad . \quad (27a)$$

ξ' follows as function of y''_1 from equation (14), hence gives:—

$$\sigma = \underset{\text{lower}}{\overset{\text{upper}}{}} \frac{Eh}{2}\left(\frac{2EJ_0}{2EJ_0 + E\Omega v^2} \pm 1\right) y''_1 \qquad . \quad . \quad . \quad (28)$$

In the corresponding edges of the right wall, the same equal and opposite stresses as in equation (28) are obtained.

III. Experiments.

The experiments were made on boxes of duralumin and plywood in order to test the conclusions of the preceding theory on open boxes and to evaluate the practical approximation.

It is anticipated that, because of the effect of self-stiffening as a result of the great form changes, the analytical results will be too unfavourable compared with reality; but in practice the analyst and the designer prefer to err on the safe side.

The foregoing theory states that the open boxes have a low over-all torsional stiffness as compared to a closed box of the same dimensions. But it does not equal zero as Bredt's theory stipulates in his particular case.

The foregoing theory further manifests that the torsional stiffness of the open box originates in the flexural stiffness of the vertical walls, the deflections of which the horizontal wall opposes. This wall undergoes no shear, it merely bends. The vertical walls are subjected to very little shear, which probably has little effect on the deformations of the system. It may be said that the system reacts predominantly with normal stresses to the applied torque, whence the term " twisting " is employed reluctantly to the type of stress considered here.

(*a*) Experiments with Closed Duralumin Box for the Experimental Determination of G.

The twisting test of the box beam with one wall lacking was preceded by the experimental determination of G for the employed duralumin sheet. This value is to be used in the calculations for the box with one wall removed. The determination of G is effected by the twisting of a thin-walled beam of square section (plots 1 and 2). The reasons for the square section were the following:—

In a rectangular, hollow, closed-off prism so supported as to permit warping, the angles of warping or dislocation of a vertical wall and those of a horizontal wall, are proportional $(h/s_1 - b/s_2)$. Now, since $h=b$ and $s_1=s_2$ on a square section of constant thickness, the angles of warping are equal to zero; *i.e.*, there is no warping. If such a box is restrained so as to prevent warping, it will have no effect whatsoever, because no normal stresses due to bending can occur. Even possibly existing flanges have no reason for positive or negative tension. All this is beneficial for the construction of a test box on which flanges along the edges are necessary. Moreover, it is simpler to clamp the box and provide a robust flange that definitely prevents warping. For this reason the shear modulus G, derived from the twist of the discussed box must be exactly correct.

For the box beam of square section of side length h, and thickness s, it gives:—

$$B = \frac{4}{4}\frac{Gh^4}{h/s} = Gh^3 s$$

The angle at the extreme end amounts to

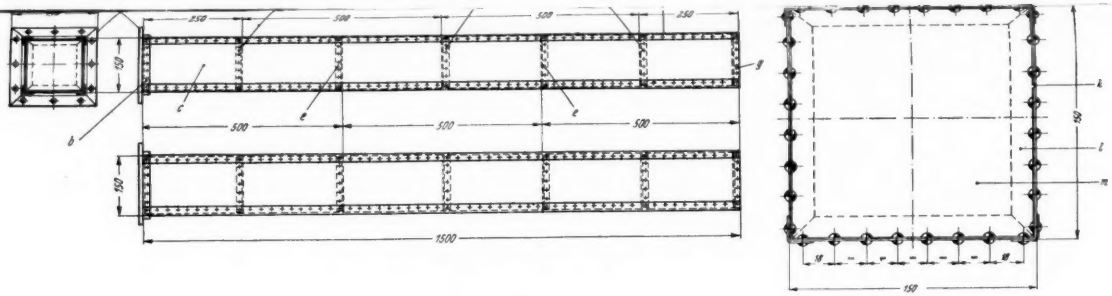
$$\delta\,(o) = \frac{M_t l}{B} = \frac{M_t l}{Gh^3 s}$$

For $l=149.5$ cm., $h=15$ cm., $s=0.06$ cm., it is:—

$$\delta\,(o) = M_t \frac{149.5}{G\ 15^3 \times 0.06}$$

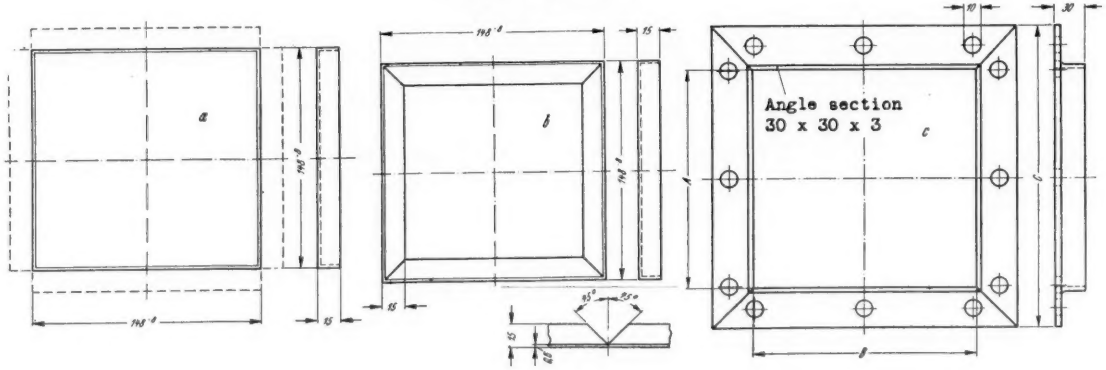
hence for G:—

$$G = \frac{149.5}{15^3 \times 0.06}\frac{M_t}{\delta\,(o)} = 0.74\frac{M_t}{\delta\,(o)}$$



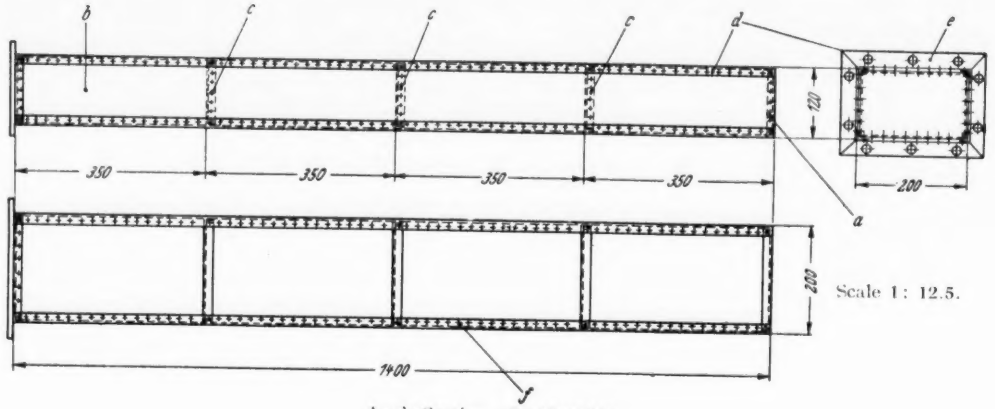
PLOT 1.

Duralumin.
Pieces: 1.
Scale 1: 12.5.
a. Attach flange.
b. Partition wall of Duralumin.
c. Duralumin.
d. Duralumin angles.
e. Duralumin partition.
f. Rivet pitch, 18 mm.
g. Partition of 8/10 mm. Duralumin parts—scale 1: 3.
h. Angle section.
i. Rivets
k. 6/10 mm. Duralumin covering.
l. Angle section.
m. Partition wall.



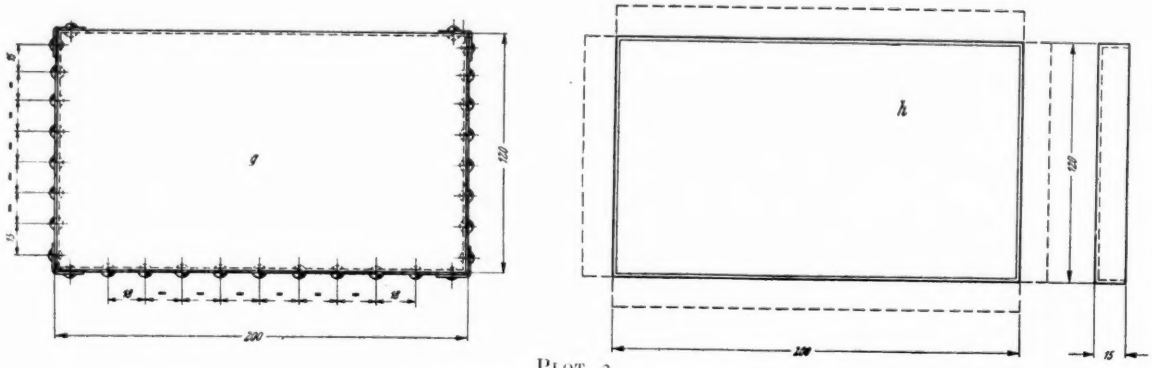
PLOT 2.

a. Partition wall of Duralumin sheet.
2 pieces of 8/10 mm. Duralumin sheet.
2 pieces of 6/10 mm. Duralumin sheet.
b. Duralumin angle section.
3 pieces of 6/10 mm. Duralumin sheet.
c. Attachment flanges.



Scale 1 : 12.5.

Angle Section $15 \times 15 \times 6/10$



PLOT 3.

a. Partitions.
b. Duralumin.
c. Partitions.
d. Angle sections.
e. Attach flange.
f. Rivet pitch.
g. Partition of Duralumin. Scale 1 : 3.5.
h. Duralumin.
2 pieces of 8/10 mm. sheet.
3 pieces of 6/10 mm. sheet.

Measuring the vertical displacements y_1 and y_2 at the ends of a horizontal bar of 1.6 m. length, and applying a torque with two equal and opposite loads P at 100 cm. distance, gives:—

$$M_t = P \times 100 \text{ kg./cm.}$$

$$\delta\,(0) = \frac{(y_1 + y_2)}{160} \text{(in radians)}$$

$$G = 0.74 \frac{P \times 100}{(y_1 + y_2)/160} = 11{,}840 \times \frac{P}{y_1 + y_2} \text{ kg./cm.}^2 \quad . \quad . \quad (29)$$

The recorded values are compiled in Table I.

TABLE I.

P kg.	y_1 cm.	y_2 cm.	y_1+y_2 cm.	$\frac{P}{y_1+y_2}$	G kg./cm.^{2}
10	0.2	0.2	0.4	25	296,000
20	0.45	0.45	0.9	22.2	263,000
30	0.65	0.65	1.3	23	272,000
40	0.95	0.95	1.9	21	249,000
50	1.25	1.25	2.5	20	237,000

The last two values for G correspond to a strain condition by incipient buckling; they are therefore apparent, not actual, G values. The test average is $G = 270{,}000$ kg./cm.^{2}.

Figs. 2 and 3 show the test rig, and Fig. 3 is the set-up with Huggenberger strain gauges, which were also used in order to obtain G by a different method.*

(*b*) LOAD TESTS.

The dimensions of the open box are given in plot 3; Fig. 4* shows the test procedure.

The torque is applied at the free end of the box by means of a double lever where the applied forces are 100 cm. apart. The box being 20 cm. wide, the force (P) is in each case $100/20 = 5$ times greater than the load exerted at the two ends of the lever during the test.

The measurements included:—

1. The two vertical, oppositely directed displacements y_s and y_d at both ends of the horizontal bar of 160 cm. length, the test point lying on the median plane of the bar attachment.
2. The horizontal displacement y_o of the lower horizontal wall. The ordinates y_s, y_d, and y_o were measured at the free end of the box.

y_o corresponds to the value $y_3\,(0)$ of the theory. y_s and y_u, reduced in ratio of the horizontal differences, correspond to the quantity $y_1\,(0) + y_2\,(0)$, or, exactly:—

$$y_1\,(0) + y_2\,(0) = \frac{20}{160} y_s = \frac{20}{160} y_d$$

For this reason the expression $20/160 \times (y_s + y_d)/2$ is used for $y_1\,(0) + y_2\,(0)$ in Table II.

TABLE II.

P kg.	y_s (left) mm.	y_d (right) mm.	y_o mm.	$y_1\,(0)+y_2\,(0)$ mm.
5	12	12.5	0.5	1.53
10	24	25	1.0	3.06
15	35	36.5	1.5	4.47
20	48.5	51	2.0	6.22
25	59	62	2.5	7.56
30	71	73	3.0	9.00

* Figs. 2, 3 and 4 (photographs) not printed.

f. Duralumin. 2 pieces of 8/10 mm. sheet.
3 pieces of 6/10 mm. sheet.
c. Attach hinge.
f. Rivet pitch.
g. Partition of Duralumin.
Scale 1 : 3.5.
a. Partitions.
b. Duralumin.
c. Partitions.
d. Angle sections.

There is a distinct proportionality between torque and strain, according to Table II. This brings us to the formulas of the preceding theory. Making $x=0$ in the expressions for y_1, y_2, and y_3 gives:—

$$y_1(0)=\frac{Pl^3}{3\,EJ_v\,(1+h^2/2\,J_v\,(2\,\Omega+b^2\,J_o))} \quad . \quad . \quad . \quad (30)$$

$$y_2(0)=\frac{Pl}{Gs_1h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

$$y_3(0)=\frac{bh\Omega}{2\,J_o+b^2\Omega}\,y_1(0) \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

Next we compute J_v, Ω, and J_o. The cross section of a flange section is 30 mm.^{2}=0.3 cm.^{2} (Fig. 5). The inertia moment of a vertical wall with two flange sections—the centroids of the flange sections being $12-(2\times0.4)=11.2$ cm. spaced apart—is:—

$$J_v=\frac{0.06\times12^3}{12}+\frac{0.3\times11.2^2}{2}=8.64+18.80=27.44\text{ cm.}^4.$$

The inertia moment of the horizontal wall is:—

$$J_o=\frac{0.06\times20^3}{12}=40\text{ cm.}^4.$$

The section Ω of one of the two vertical walls, inclusive of both flange sections is:—

$$\Omega=0.06\times12+2\times0.3=1.32\text{ cm.}^2$$

$$EJ_v\left(1+\frac{h^2}{2\,J_v\,(2\,\Omega+b^2\,J_o)}\right)=zEJ_v \quad . \quad . \quad . \quad (33)$$

whereby

$$z=1+\frac{h^2}{2\,J_v\,(2\,\Omega+b^2\,J_o)} \quad . \quad . \quad . \quad . \quad (34)$$

z is a kind of enlargement factor of EJ_v, which includes the supplemental horizontal wall.

$$z=1+\frac{12^2}{2\times27.44\,(2/1.32+20^2/40)}=1.228$$

$$zEJ_v=1.228\times750{,}000\times27.44=26.3\times10^6\text{ kg./cm.}^2.$$

The box length without the clamping flange is about 135 cm.

$$\left.\begin{aligned}y_1(0)+y_2(0)&=\frac{Pl^3}{3\,zEJ_v}+\frac{Pl}{Gs_1h}\\&=P\,\frac{135^3}{3\times26.3\times10^6}+\frac{135}{270{,}000\times0.06\times12}\\&=P\,(0.0312+0.0007)=0.0319\,P\end{aligned}\right\} \quad . \quad . \quad (35)$$

Then

$$y_1(0)=0.0312\,P$$

hence

$$\left.\begin{aligned}y_3(0)&=\frac{bh\Omega}{2\,J_o+b^2\Omega}\,y_1(0)=\frac{20\times12\times1.32}{2\times40+20^2\times1.32}\,y_1(0)\\&=0.521\;y_1(0)=0.521\times0.0312\;P=0.01625\;P\end{aligned}\right\} \quad . \quad (36)$$

With $P=30$ kg., $y_1(0)+y_2(0)=0.319\times30=0.957$ cm. against the 0.9 cm. test value. For $y_3(0)=0.01625\times30=0.48$ cm. against the experimental 0.3 cm. The accord between theory and test is satisfactory.

(*c*) Tests on Closed Plywood Box—Determination of G.

The box was a thin-walled beam of square section. The dimensions were those of the duralumin specimen (plots 1 and 2). The walls were of 1.5 mm.

birch plywood. The walls and the partitions were connected by 10×10 mm.^{2} strips. The two partitions at the end were of 2 mm. birch plywood. The 15×15 mm.^{2} flange strips were of spruce (Figs. 6 and 7).

The distance of the couple and of the test scale was $d = 112$ cm. The test arrangement is shown in Fig. 8.* It is

$$B = \frac{4\,S^2}{\int_c ds/s} G = \frac{4\,h^4}{4\,h/s} G = Gh^3 s \quad . \quad . \quad . \quad . \quad (37)$$

$$\delta\,(o) = \frac{M_t l}{B} = \frac{Pdl}{Gh^3 s} = \frac{y_d + y_s}{d} \quad . \quad . \quad . \quad . \quad (38)$$

y_d and y_s are the respective readings from the right and left test scale.

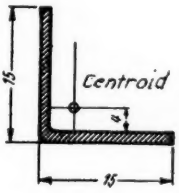


FIG. 5.
Flange profile.

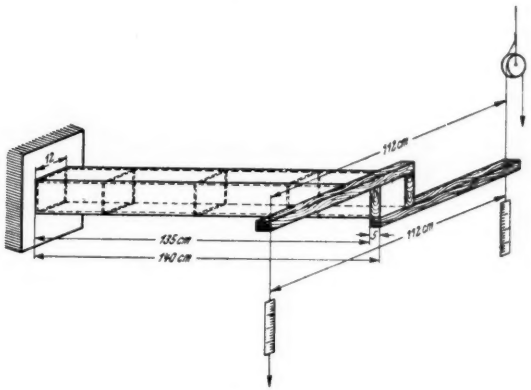


FIG. 6.
Test rig with closed plywood box to define G.

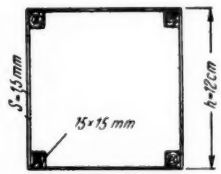


FIG. 7.
Section through box.

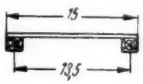


FIG. 11.
Wall section.

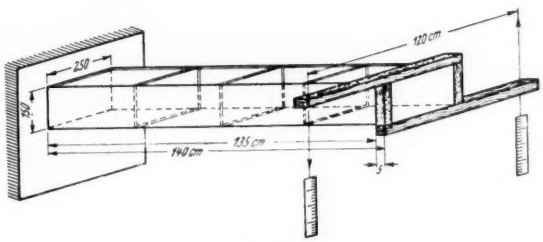


FIG. 9.
Test rig with open plywood box.

* Not printed.

According to equation (38), the experimental value of G is:—

$$G=\frac{Pd^2l}{h^3s\,(y_d+y_s)}=6{,}770\frac{P}{y_d+y_s} \quad . \quad . \quad . \quad . \quad (39)$$

TABLE III.

Load P kg.	y_d mm.	y_s mm.	y_d+y_s mm.	$\frac{P}{y_d+y_s}$	G kg./cm.^{2}
5	12.5	12	24.5	2.04	13,800
10	25	24	49	2.04	13,800
15	41	39	80	1.875	12,700
20	58	55	113	1.77	12,000
25	78	76	154	1.62	11,000

Since critical phenomena appear at $P=15$ kg., the value $G=13{,}800$ kg./cm.^{2} is maintained.

Putting $m=3$, would give:—

$$E=\frac{2\,(m+1)}{m}G=2.67\times 13{,}800=36{,}800 \text{ kg./cm.}^2$$

(*d*) LOAD TESTS WITH OPEN PLYWOOD BOX.

The dimensions are given in Fig. 9. The side walls and the partitions are of 1.5 mm. birch plywood, the outside bulkhead walls of 2 mm. birch plywood. The flange strips are of 15×15 mm.^{2} spruce. The test arrangement is shown in Fig. 10.*

As shown in section II, it is:—

$$y_1\,(o)=\frac{Pl^3}{3\,EJ_v1+h^2/2\,J_v\,(2/\Omega+b^2/J_o)} \quad . \quad . \quad . \quad (40)$$

with $h=15$ cm., $b=25$ cm., and s (wall thickness) $=0.15$ cm. Now the walls of the box have a $G=13{,}800$ kg./cm.^{2}, and an $E=36{,}800$ kg./cm.^{2}, as established by tests. But for the spruce strips, it is around $E=100{,}000$ kg./cm.^{2}. So in the calculation of Ω (section of one wall including strips) and for J_v (their inertia moment) as is customary in reinforced concrete, the area of the spruce, *i.e.*, that of the harder material, must be multiplied by

$$n=\frac{E_{\text{spruce}}}{E_{\text{plywood}}}=\frac{100{,}000}{36{,}000}=\sim 3$$

Hence (Fig. 11):—

$$\Omega=0.15\times 15+3\times 2\times 1.5^2=15.75 \text{ cm.}^2 \quad . \quad . \quad . \quad (41)$$

$$J_v=0.15\times\frac{15^3}{12}+3\times 1.5^2\,\frac{13.5^2}{2}=656 \text{ cm.}^4 \quad . \quad . \quad . \quad (42)$$

$$\frac{b^2}{J_o}=\frac{25^2}{0.15\times 25^3/12}=\frac{12}{0.15\times 25}=3.2 \quad . \quad . \quad . \quad (43)$$

$$\frac{2}{\Omega}+\frac{b^2}{J_o}=\frac{2}{15.75}+3.2=0.127+3.2=3.327 \quad . \quad . \quad . \quad (44)$$

$$\frac{h^2}{2\,J_v\,(2/\Omega+b^2/J_v)}=\frac{15^2}{2\times 656\times 3.327}=0.0515 \quad . \quad . \quad . \quad (45)$$

$$y_1\,(o)=\frac{P\,135^3}{3\times 36{,}800\times 656\times 1.0515}=0.0336\,P \quad . \quad . \quad (46)$$

$$y_2\,(o)=\frac{P\,135}{13{,}800\times 0.15\times 15}=0.00434\,P \quad . \quad . \quad . \quad (47)$$

* Not printed.

$$y_1(o) + y_2(o) = (0.0336 + 0.00434)\,P = 0.03794\,P \quad . \quad . \quad (48)$$

$$\delta(o) = \frac{2 \times 0.038\,P}{25} = 0.00304\,P \quad . \quad . \quad . \quad . \quad (49)$$

Take, for example, the 10 kg. load, bear in mind that the distance between the couple is 120 cm., and that $b = 25$ cm. Then,

$$P = \frac{120}{25}\,10 = 48 \text{ kg.}$$

$$\delta(o)_{\text{computed}} = 0.00304 \times 48 = 0.146$$

instead of an observed test value of 7.8 cm., which corresponds to

$$\delta(o)_{\text{recorded}} = \frac{2 \times 7.8}{120} = 0.13.$$

Here also the agreement between theory and test is satisfactory.

The loads, the proportional moments M_t, and the recorded strains along with the theoretical and experimental values of $\delta(o)$, are compiled in Table IV.

TABLE IV.

kg.	$M_t = P \times 120$ kg./cm.	y_d (right) mm.	y_s (left) mm.	$\delta(O)$ recorded in radians	$\delta(O)$ computed in radians
5	600	32	32	0.053	0.073
6	720	41	41	0.067	0.087
7	840	50	49	0.082	0.102
8	960	61	60	0.101	0.117
9	1080	69	67	0.114	0.131
10	1200	79	77	0.130	0.146
11	1320	88	86	0.145	0.160
0	—	6	5	—	—

Translation by J. Vanier, National Advisory Committee for Aeronautics.

REFERENCE.

1. Minelli, C. Nuovo calcolo energetico-variazionale di "travi a cassone" sottoposte a torsione. Ricerche di ingegneria, Nov.-Dec. 1937.

STRESSES IN SINGLE-SPAR WING CONSTRUCTIONS WITH INCOMPLETELY BUILT-UP RIBS.*

By F. Reinitzhuber.

I. Introduction.

The constructional elements of single-spar wing structures are main spars, torsion tubes, ribs, and auxiliary spars. The ribs, which generally extend over the entire wing section, are for the purpose of stiffening the torsion tubes and taking up the forces in the torsion tubes and in the main spar. Mounted structures in the wing, engine, and landing gear often make it necessary to build up only one-half of the wing cross section completely with flanges and webs as a flexural supporting member. The other half of section is then omitted entirely or only the flanges are retained. As long as only small forces are to be taken up by such incompletely built-up ribs and the distances of the latter from the neighbouring fully built-up ribs are not too large (Fig. 1), an accurate investiga-

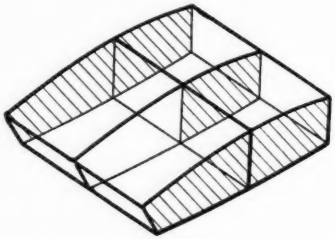


Fig. 1.

Portion of a single-spar wing with incompletely formed rib.

tion is not necessary. The effect of the incomplete rib may then be neglected and the applied loads distributed over the neighbouring complete ribs. If, however, large forces due to the engine or landing gear are to be applied to the incomplete ribs, it is necessary to investigate the force distribution in detail, as will be done below.

II. Load Assumptions.

A single-spar wing structure is investigated, having two auxiliary spars (front and rear), several fully built-up ribs, and two neighbouring incompletely built-up ribs. In the rear torsion tubes of the latter, the webbing is missing so that only the flanges remain. Of the several complete ribs only the two are considered that are on each side of the incomplete ribs. This is sufficient to determine the qualitative effect of the disturbance due to the incomplete ribs; the quantitative disturbance will also be small. The investigation is therefore extended over the

* "Über die Krafteinleitung in einholmige Flügeltragwerke durch unvollkommen ausgebildete Querwände." Luftfahrtforschung, Vol. 16, No. 7, July 20, 1939, pp. 349-354.

Technical Memorandum No. 937, National Advisory Committee for Aeronautics. Reprinted by courtesy of the Committee.

portion of the wing shown in Figure 2, the wing being attached with no deformation restraint at rib 5.

The above wing portion is loaded by normal and tangential transverse forces and torsional moments which arise at the outer wing and act on rib 0. Furthermore, local forces from the engine and the landing gear are applied at the front half of ribs 2 and 3. The forces due to the outer part of the wing are only slightly changed by the incomplete construction of ribs 2 and 3 as far as their distribution over the wing section is concerned. This type of loading will therefore not further be investigated and only the force distribution due to the applied loads at ribs 2 and 3 will be considered. Since the computation for applied tangential or normal forces or torsion moments is fundamentally the same, but the torsion moments for the shear in the wing covering are of chief importance the present study will be restricted to the investigation of the torsion moments only.

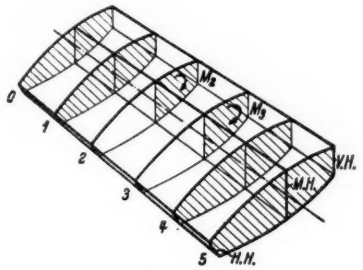


FIG. 2.

Portion of a single-spar wing with two auxiliary spars and two incompletely formed ribs.

III. COMPUTATION OF THE WING PORTION INVESTIGATED BY THE "SHEAR FIELD METHOD."

The computation of systems that consist of shear skins, flanges, and ribs is most suitably carried out by the "shear field method" often employed. This method is characterised by the assumption of a pure shear condition in the sheet panels between the flanges and the stiffeners while all the axial forces are assigned to the spars and stiffeners through the use of an "effective width."* A computation based on these assumptions follows the methods that are employed for statically indeterminate computations.

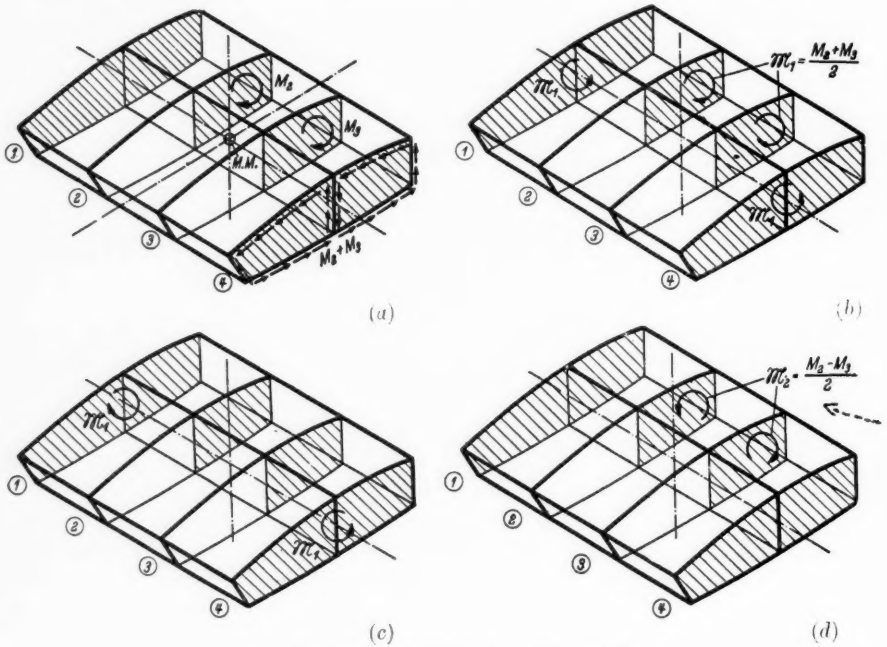
The number of static indeterminates for the wing portion shown in Figure 2 fixed at rib 5 with no deformation restraint (with 3 longitudinal ties) is $4 \times 3 + 5 \times 1 - 2 = 15$, since the double cells between two neighbouring ribs are connected each by three redundant longitudinal ties; furthermore, each double cell is statically indeterminate with the exception of the cells 1-2 and 3-4 for which through the omission of the web sheet at each half of the ribs 2 and 3 the number of static redundancies is decreased by two.

The computation of highly redundant statically indeterminate systems, which consist of double cells, has been carried out for space frameworks in a work of H. Ebner and H. Köller (reference 2). Three forces groups, obtained by disconnecting the three redundant longitudinal ties at each rib, and a suitable shear at each double cell (in the case of torsion loading, the shear at the centre spar) are introduced as the static indeterminates. In the region of the ribs 1 to 4, it is to be noted that by the omission of the web sheets in the rear half of ribs 2 and 3 there are two static redundancies fewer than in the other double cells.

* A detailed description of the shear field method is found, for example, in reference 1.

For this reason, in this portion of the double cells, instead of three undetermined shears, only one need be introduced, most suitably chosen in the web of the rear spar.*

After this choice of the static redundancies, the 15 elasticity equations may be set up whose solution then gives the values of the static indeterminates, which may be slightly or not at all coupled. The work of computation still remains extremely large. If the portion of the wing under consideration were extended by using more double cells, the number of static indeterminates and hence the work of computation would still further increase considerably. It is therefore necessary to make simplifying assumptions that will enable us to obtain a general



a. *W system with loading* M_2 *and* M_3.
b. *Loading case* W_1.
c. ,, ,, W_2.
d. ,, ,, W_3.

FIG. 3*a* to *d*.

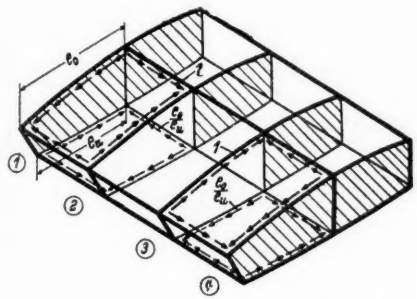
Decomposing of the loading M_2 *and* M_3 *in the W system into the loading cases* W_1, W_2, W_3 ($W = W_1 + W_2 + W_3$).

idea of the force distribution in wings resulting from the application of forces at incomplete ribs without the necessity for carrying out the large computation work. The simplifications refer to the manner of loading the system and the choice of the static indeterminates.

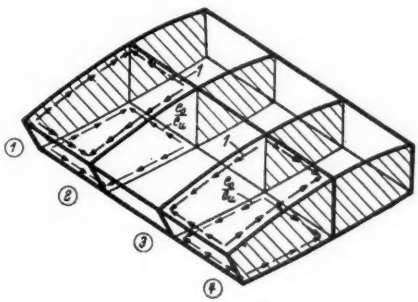
The forces in cells 0-1 and 4-5 are not of decided importance for the distribution of the forces in the torsion tubes. They are neglected by disconnecting

* Another method of computation for the problem under consideration is presented in a paper by H. Köller (reference 3). The method there indicated is conveniently applied if the web sheet in the rear portion of the incomplete ribs is removed after a statically indeterminate computation had already been carried out for complete ribs.

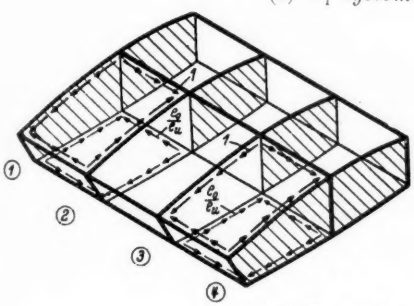
longitudinal ties at ribs 1 and 4. Considering the ribs 1 and 4 as stiff, then cell 0-1 is without stress and the cell 4-5 distributes the applied torsional moment in proportion to the stiffness of the forward and rear torsion tubes. (See reference 4.) The cells 0-1 and 4-5 may therefore be omitted. There then remains to investigate the sevenfold statically indeterminate W system of Figure 3*a*. In most practically occurring cases, the system will be symmetrical with respect to a plane parallel to the ribs through MM or may be assumed symmetrical through suitable averaging. In symmetrical systems, it is convenient to decompose the load into symmetric and skew-symmetric groups. The moments M_2 and M_3 applied in the W system are split up into three load cases,



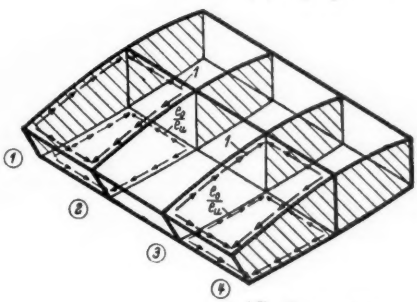
(*a*) X_1 *system.*



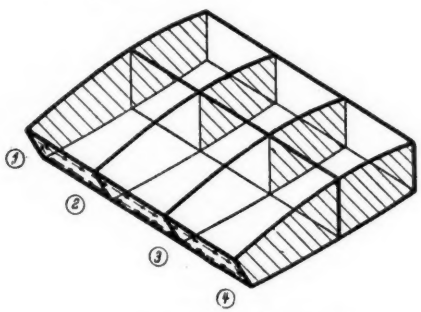
(*b*) X_2 *system.*



(*c*) X_3 *system.*



(*d*) X_4 *system.*



(*e*) X_5 *system.*

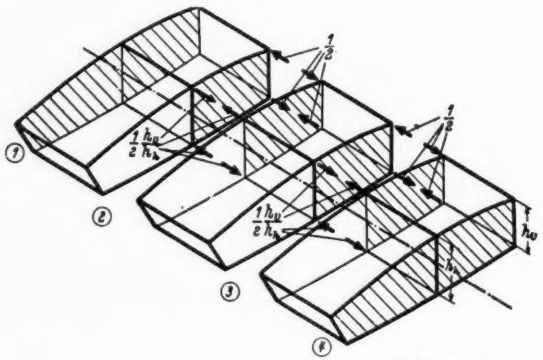
FIG. 4*a* to *e*.

Static indeterminates X_1 to X_5.
(There are shown only the shears at an edge.)

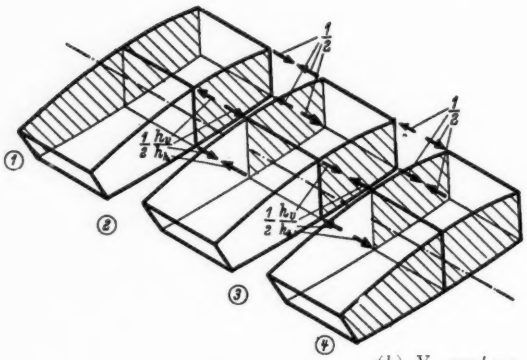
W_1, W_2, and W_3, represented in Figures 3*b*, 3*c*, and 3*d*. Of the three cases, only the W_1 and W_3 systems are of significance for the statically indeterminate computation. The W_2 system distributes the moment

$$M_1 = \frac{M_2 + M_3}{2}$$

in proportion to the stiffness of the forward and rear torsion tubes and needs no further investigation.



(*a*) Y_1 *system.*



(*b*) Y_2 *system.*

FIG. 5*a*, *b*.

Static indeterminates Y_1 and Y_2 of the base system.

It is now necessary to choose the 7 static redundancies. By cutting through 5 sheets, namely, those bounded by the centre and rear spars and the ribs 1, 2, and 3, 4, respectively, and the web sheet of the rear spar the sevenfold statically indeterminate system is reduced to a fivefold statically indeterminate system and a twofold statically indeterminate base system. The 5 static indeterminates, $X_1, \ldots X_5$, which are made up of the unknown shears of the 5 sheets cut through are shown in Figures 4*a*, *b*, *c*, *d*.* They are so chosen as to be only slightly coupled with one another. The equation coefficients corresponding to the elasticity equations therefore become

$$\delta^x_{1\cdot3} = \delta^x_{1\cdot4} = \delta^x_{1\cdot5} = 0 \text{ and } \delta^x_{2\cdot3} = \delta^x_{2\cdot4} = \delta^x_{2\cdot5} = 0.$$

* The use of shears as static indeterminates is also found in reference 5.

The remaining coupling members, however, $\delta^{x}_{1\cdot 2}$, $\delta^{x}_{3\cdot 4}$, $\delta^{x}_{4\cdot 5}$, are also small in comparison with $\delta^{x}_{1\cdot 1}, \ldots \delta^{x}_{5\cdot 5}$. The $X_1 \ldots X_4$ systems can also be represented as force groups by loosening the longitudinal ties in the rear spar at ribs 10 and 11 or by cutting the flanges of the ribs at the centre spar.

The twofold statically indeterminate base system, which consists of a closed torsion tube extending from ribs 1 to 4, is converted into the statically determinate null system by loosening a longitudinal tie at ribs 2 and 3. The force groups Y_1 and Y_2 in Figure 5 are taken as the static indeterminates. In this manner, the seven static indeterminates are chosen. Y_1 and Y_2 are not coupled ($\delta^{y}_{1\cdot 2}=0$). In the X_1 and X_2 systems $Y_2=0$, in the X_3, X_4, and X_5 systems $Y_1=0$. For the W_1 loading case $Y_2=0$ and $X_3=X_4=X_5=0$, for the W_3 loading case $Y_1=0$ and $X_1=X_2=0$. The elasticity equations for the loading group W_1 are therefore

$$\delta^{x}_{1\cdot 1}X_1+\delta^{x}_{1\cdot 2}X_2+\delta^{x}_{1\cdot 0}=0$$
$$\delta^{x}_{2\cdot 1}X_1+\delta^{x}_{2\cdot 2}X_2+\delta^{x}_{2\cdot 0}=0$$

and for the loading group W_3:—

$$\delta^{x}_{3\cdot 3}X_3+\delta^{x}_{3\cdot 4}X_4+\delta^{x}_{3\cdot 5}X_5+\delta^{x}_{3\cdot 0}=0$$
$$\delta^{x}_{4\cdot 3}X_3+\delta^{x}_{4\cdot 4}X_4+\delta^{x}_{4\cdot 5}X_5+\delta^{x}_{4\cdot 0}=0$$
$$\delta^{x}_{5\cdot 3}X_3+\delta^{x}_{5\cdot 4}X_4+\delta^{x}_{5\cdot 5}X_5+\delta^{x}_{5\cdot 0}=0$$

where the $\delta^{x}_{i,k}$ and $\delta^{x}_{i,0}$ values are to be determined from a simple statically indeterminate base system. In the loading case W_1 and the X_1, X_2 systems, the elasticity equation of the statically indeterminate base system is

$$\delta^{y}_{1\cdot 1}Y_1+\delta^{y}_{1\cdot 0}=0$$

similarly in the loading case W_3 and the X_3, X_4, X_5 systems

$$\delta^{y}_{2\cdot 2}Y_2+\delta^{y}_{2\cdot 0}=0.$$

The solution of the sevenfold statically indeterminate problem is thus reduced to a twofold (W_1) and a threefold (W_3) statically indeterminate problem each with a simply indeterminate base system.

For approximate computations, the static redundancies Y_1 and Y_2 of the base system may be neglected. The static indeterminate X_2 for the loading case W_1 is small and may be set equal to zero. There is then obtained

$$X_1 \cong -\frac{\delta^{x}_{1\cdot 0}}{\delta^{x}_{1\cdot 1}}$$

an approximate value which gives useful results for the most important loading case W_1. If, instead of the torsion moment M_1 of the W_1 loading case, two tangential forces act as external load on ribs 2 and 3, there is obtained as approximate value, since $X_1 \cong 0$

$$X_2=-\frac{\delta^{x}_{2\cdot 0}}{\delta^{x}_{2\cdot 2}}$$

Having determined the force distribution in the W system, the characteristic force groups which arise from the deformation restraint at ribs 1 and 4 and were up to now neglected, may be determined in a supplementary computation. Their effect on the distribution of the applied forces in the front and rear tubes is small, however, as will appear from the numerical example in the following section.

IV. Illustrative Example.

The numerical computation will be carried out for the wing portion shown in Figure 6*a*. Tables I*a* to I*d* give the thickness of the sheets and stiffener cross sections. The covering and spar webs were assumed as rigid in shear while the webs of the ribs were considered as tension fields. Deviating from the system shown in Figure 3, the covering between ribs 2 and 3 in the rear wing portion is not part of a cylindrical shell corresponding to the engine nacelle but

has the shape shown in Figure 7. In this case, too, under transverse loading a pure shear stress condition is obtained. The shear flow is

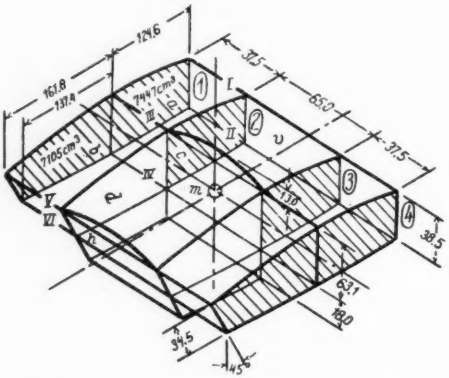
$$t_x = t_o\left(\frac{h_o}{h_x}\right)^2$$

The virtual work obtained is thus

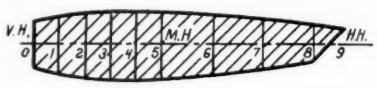
$$\int \frac{t_x^{(a)} t_x^{(m)} dF_x}{sG} = t_o^{(n)} t_o^{(m)} \frac{F_{red}}{sG} F_{red} = l_o H,$$

$$\text{where } H = \int \left(\frac{h_o}{h_x}\right)^3 ds$$

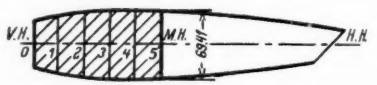
an expression which formally agrees with that for parts of cylindrical shells. Instead of the entire area that must be substituted in cylindrical shells, there enters a reduced area with which the computation is carried out as with cylindrical shells.



(a) *Portion of a single-spar wing with two auxiliary spars and two incompletely formed ribs. a, b, upper covering; c, d, lower covering; r, m, h, spar webs; I, II, III, IV, V, VI, spar flanges.*



(b) *Ribs 1 and 4.*



(c) *Incomplete ribs 2 and 3.*

FIG. 6a to c.

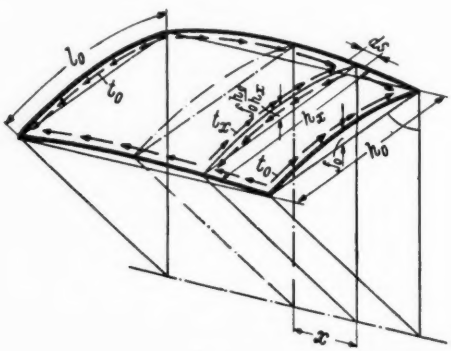


FIG. 7.
Portion of covering sheet.

TABLE I*a*.

Ratio s_c/s of Thickness of Sheet of Covering and Spar Web (see Fig. 6*a*).

Cell.	Covering.					Spar Web.	
	a	*b*	*c*	*d*	*v*	*m*	*h*
1-2 } 3-4 }	1.0	0.930	1.0	0.833	0.909	1.0	1.0
2-3	1.0	0.833	1.0	0.833	0.833	1.0	1.0

TABLE I*b*.

Thickness Ratio s_c/F (cm.$^{-1}$) of Cross Sections of the Spar Flanges (see Fig. 6*a*).

Cell.	Front Spar.		Centre Spar.		Rear Spar.	
	I	II	III	IV	V	VI
1-2 } 3-4 }	0.0406	0.0348	0.0031	0.0038	0.0367	0.0360
2-3	0.0406	0.0348	0.0031	0.0038	0.0435	0.0435

TABLE I*c*.

Ratio s_c/s of Thickness of Sheet of the Webbing of Ribs 1, 4 and 2, 3 (see Fig. 6*b*, *c*).

Rib.	Panel.							
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
1 and 4	0.500	1.00	1.00	1.00	0.500	0.833	0.833	0.833
2 and 3	0.313	0.625	0.625	0.625	0.313	—	—	—

TABLE I*d*.

Thickness Ratio s_c/F (cm.$^{-1}$) of Cross Sections of Flanges of Ribs 1, 4, and 2, 3 (see Fig. 6*b*, *c*).

Rib.		Panel.								
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
1 and 4	O.G.[a]	0.0261	0.0261	0.0167	0.0167	0.0153	0.0148	0.0193	0.0260	0.0476
	U.G.[b]	—	—	—	—	—	0.0162	0.0253	0.0481	0.0865
2 and 3	O.G.			0.0270			0.0238	($s_c/J = 0.0588$ cm.$^{-3}$)		
	U.G.						0.0520			

(a) Upper flange. (b) Lower flange.

TABLE II*a*.

Assumptions Made in Numerical Example on the Elastic Behaviour of the Ribs and on the Manner of Load Application.

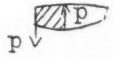
Case.	Ribs 1, 4 and front half of ribs 2, 3.	Flanges in rear part of ribs 2, 3.	Moment application at ribs 2, 3.
1	Rigid	Rigid	—
2	Elastic	Elastic	
3	Elastic	Elastic	
4	Rigid	Elastic	—

TABLE II*b*.

Assumptions Made in Numerical Example on Deformability of Double Cells and on the Number of Static Indeterminates.

Case	Fixity conditions at ribs 1 and 4.	Assumptions on the deformation forces in front tubes and ribs 2 and 3.	Number of static indeterminates W_1	W_3
A	Restraint against deformation by assumption of inelastic cells 0-1 and 4-5.	Deformation forces in front tubes at ribs 2 and 3 taken into account.	6	7
B			3	4
C		Deformation forces in front tubes and ribs 2 and 3 are neglected ($Y_1=0$, $Y_2=0$) (Case *D*, $X_2=0$)	2	3
D	No restraint against deformation at ribs 1 and 4.		1	–

For the numerical computation, various assumptions were made with reference to the stiffness of the ribs and the reduction of the static redundancies and these are given in Tables II*a*, *b*. If a value $M_1=1{,}000$ kg. m. is chosen for loading case W_1 (Fig. 3*b*), then the shears of the covering and spar webs and the flange forces of the spars are those given in Tables III*a*, *b*.

TABLE III*a*.

Shear Flows (kg./cm.) of Covering and Spar Webs in Symmetric Loading Case W_1* (see Fig. 3*b*).

Cell.	Case.		Covering. *a*	*b*	*c*	*d*	*v*	Spar Web. *m*	*h*
	1	A	$\mp$2.89	$\mp$3.39	$\pm$3.25	$\pm$3.66	$\mp$6.77	$\pm$3.16	0
		B	$\mp$3.55	$\mp$3.20	$\pm$3.91	$\pm$3.44	$\mp$5.84	$\pm$2.97	0
		C	$\mp$4.21	$\mp$3.24	$\pm$4.52	$\pm$3.53	$\mp$4.36	$\pm$2.28	0
		D	$\mp$4.36	$\mp$3.12	$\pm$4.36	$\pm$3.68	$\mp$4.36	$\pm$2.32	0
	2	B	$\mp$6.41	$\mp$1.12	$\pm$1.91	$\pm$5.40	$\mp$5.46	$\pm$3.68	0
1–2		C	$\mp$6.90	$\mp$1.04	$\pm$2.34	$\pm$5.36	$\mp$4.62	$\pm$3.38	0
		D	$\mp$4.71	$\mp$2.66	$\pm$4.71	$\pm$3.13	$\mp$4.71	$\pm$2.97	0
and		B	$\mp$4.51	$\mp$1.66	$\pm$4.54	$\pm$1.92	$\mp$7.47	$\pm$5.25	0
3–4	3	C	$\mp$5.54	$\mp$1.57	$\pm$5.50	$\pm$1.88	$\mp$5.52	$\pm$4.49	0
		D	$\mp$5.52	$\mp$1.58	$\pm$5.52	$\pm$1.86	$\mp$5.52	$\pm$4.49	0
	4	A	$\mp$4.49	$\mp$1.10	$\pm$4.43	$\pm$1.35	$\mp$8.84	$\pm$6.40	0
		B	$\mp$5.10	$\mp$1.09	$\pm$5.05	$\pm$1.33	$\mp$7.56	$\pm$5.88	0
		C	$\mp$5.89	$\mp$1.11	$\pm$5.82	$\pm$1.38	$\mp$5.86	$\pm$5.12	0
		D	$\mp$5.86	$\mp$1.14	$\pm$5.86	$\pm$1.34	$\mp$5.86	$\pm$5.12	0
2–3	1–4	A–D	0	0	0	0	0	0	0

Upper sign applies to cell 1-2; lower to cell 3-4.

* Shears in the covering on the fuselage side of a section normal to the wing axis directed opposite to the flight direction are positive.

Shears in the covering on the fuselage side of a section normal to the wing axis directed upward are positive.

TABLE III*b*.

Flange Forces (kg.) of Spars in Symmetric Loading Case W_1* (see Fig. 3*b*).

Rib.	Case.		Front Spar. I	Front Spar. II	Centre Spar. III	Centre Spar. IV	Rear Spar. V	Rear Spar. VI
1	1	A	+106.6	−96.8	−100.5	+98.2	+93.1	−100.7
		B–D						
and	2, 3	B–D	0	0	0	0	0	0
		B–D						
4	4	A	+119.5	−121.1	−83.0	+91.3	+30.3	−37.0
	1	A	−39.1	+35.4	+36.6	−35.8	−34.0	+36.9
		B	−86.1	+72.5	+98.2	−93.8	−119.9	+129.0
		C	−5.8	−5.8	+49.3	−48.9	−121.5	+132.6
		D	0	0	+40.6	−61.5	−117.1	+138.0
	2	B	+35.9	+132.9	−60.9	−268.5	−41.8	+202.5
2		C	+85.5	+85.5	−92.7	−240.3	−39.1	+201.2
		D	0	0	+34.6	−52.4	−99.8	+117.6
and		B	−111.0	+109.7	+89.7	−98.4	−62.1	+72.0
3	3	C	+0.6	+0.6	+19.6	−32.6	−58.8	+70.5
		D	0	0	+20.5	−31.1	−59.2	+69.8
		A	−43.6	+44.2	+30.2	−33.3	−11.1	+13.6
	4	B	−92.3	+94.4	+69.7	−81.1	−40.9	+50.1
		C	+1.4	+1.4	+12.6	−25.6	−41.6	+51.7
		D	0	0	+14.8	−22.4	−42.6	+50.2

* Tensions in the flanges are positive.

TABLE IV.

Horizontal Components P_o and P_u of Flange Forces of Ribs 2 and 3 at Centre Spar and Moment M_h of Rear Tubes in Symmetric Case W_1.

Case	A P_o / P_u	A M_h	B P_o / P_u	B M_h	C P_o / P_u	C M_h	D P_o / P_u	D M_h
1	+548.7	0.364	+517.5	0.343	+524.1	0.350	+505.4	0.351
	−500.9	M_1	−472.3	M_1	−485.6	M_1	−505.4	M_1
2	—	—	+180.5	0.320	+168.7	0.314	+430.7	0.299
	—		−741.6	M_1	−736.8	M_1	−430.7	M_1
3	—	—	+268.0	0.185	+253.7	0.178	+255.7	0.178
	—		−263.7	M_1	−258.1	M_1	−255.7	M_1
4	+178.3	0.126	+176.4	0.125	+179.6	0.128	+183.8	0.128
	−185.5	M_1	−183.4	M_1	−189.1	M_1	−183.8	M_1

A clear picture of the effect of the various assumptions of Table II is obtained from Table IV by comparing the horizontal components P_o and P_u of the flange forces of ribs 2 and 3 at the centre spar. The table also shows the moment contributions M_h of the rear tubes obtained from

$$M_h = \frac{P_o + P_u}{2} h,$$

where $h = 69.41$ cm. is the distance between the rib flanges at the centre spar. If $P_o \cong P_u$, the force distribution in the covering of the rear tubes is essentially given through M_h. It may be seen that the flange forces and the moment in the rear tubes depend on the stiffness of the ribs, particularly of the flanges in the incompletely built-up rear part of the ribs 2 and 3. For this reason, it is

convenient in the case of curved sheet to place the flanges in the rear part of ribs 2 and 3 outside of the wing profile in order to keep the bending moments in the flanges small so that the flanges become stiffer. If the latter are assumed as rigid (case 1), the moment contribution of the rear tubes is 0.364 M_1 (case A, complete restraint against deformation) and 0.343 M_1 (case B, no restraint). If they are taken to be elastic (case 4), the moment drops to 0.126 M_1 and 0.125 M_1, respectively. If, in addition to the flanges in the rear part of ribs 2 and 3, the front parts and ribs 1 and 4 are assumed elastic, the moment increases to 0.185 M_1 (case 3) and 0.320 M_1 (case 2) but is essentially dependent on the manner of force application. If ribs 2 and 3 were made complete over the entire cross section of the torsion tubes then, for ribs assumed stiff without taking account of the deformation forces, the moment of the rear tubes would be 0.472 M_1.

TABLE V*a*.

Shear Flows (kg./cm.) of Covering and Spar Webs in Antisymmetrical Loading Case W_3* (see Fig. 3*d*).

Cell.	Case.		Covering. *a*	*b*	*c*	*d*	Spar Web. *v*	*m*	*h*
		A	−0.08	−0.70	+0.74	+1.08	−1.07	+2.10	−4.80
1–2	1	B	+0.35	−0.44	+0.71	+0.19	−1.70	+2.16	−3.50
		C	−0.12	−0.49	+1.16	+0.27	−0.64	+1.68	−3.56
and		A	−0.99	+0.83	+0.99	−0.32	−2.11	+3.48	−3.65
3–4	4	B	−0.65	+0.96	+0.77	−0.74	−2.61	+3.49	−2.81
		C	−1.27	+0.96	+1.38	−0.72	−1.32	+2.95	−2.85
		A	+2.63	+2.88	−3.79	−1.49	+5.40	−2.94	−0.07
	1	B	+2.96	+2.96	−4.18	−1.76	+5.32	−3.66	+1.84
		C	+3.48	+3.01	−4.68	−1.82	+4.08	−3.10	+1.93
2–3		A	+3.98	+1.47	−4.13	−0.94	+6.74	−4.54	−0.85
	4	B	+4.22	+1.59	−4.36	−1.24	+6.49	−4.94	+0.68
		C	+4.91	+1.61	−5.03	−1.27	+4.97	−4.28	+0.71

* Shears in the covering on the fuselage side of a section normal to the wing axis directed opposite to the flight direction are positive.

Shears in the covering on the fuselage side of a section normal to the wing axis directed upward are positive.

TABLE V*b*.

Flange Forces (kg.) of Spars in Antisymmetrical Loading Case W_3* (see Fig. 3*d*).

Rib.	Case.		Front Spar. I	II	Centre Spar. III	IV	Rear Spar. V	VI
1	1	A	∓53.1	±40.3	∓6.2	±52.5	±122.9	∓156.4
		B–C	0	0	0	0	0	0
and		A	∓47.7	±42.7	∓0.5	±26.1	±89.8	∓110.4
4	4	B–C	0	0	0	0	0	0
		A	∓90.2	±52.5	±96.0	∓38.9	∓83.4	±64.0
2	1	B	∓76.9	±37.3	±110.8	∓61.6	∓147.8	±138.2
		C	∓19.5	∓19.5	±77.1	∓29.7	∓152.2	±143.8
and		A	∓89.5	±84.5	±61.8	∓55.2	∓16.1	±14.5
3	4	B	∓73.6	±69.0	±70.5	∓73.9	∓69.2	±77.3
		C	∓2.0	∓2.0	±27.1	∓31.9	∓70.8	±79.7

* Tensions in the flanges are positive.

The deformation restraint at ribs 1 and 4 leads in case 1 (sixfold statically indeterminate) and in case 4 (threefold statically indeterminate) to only small changes in the moments (from 0.364 M_1 to 0.343 M_1 and from 0.126 M_1 to 0.125 M_1), so that the neglect of cells 0-1 and 4-5 appears justified. Good approximate solutions are given by cases C (twofold statically indeterminate) and D (simply statically indeterminate) for the shears of the covering and the spar webs but not for the flange forces which chiefly depend on the neglected deformation restraint. In an approximate computation, however, the latter are of no particular importance, since they play the part of additional forces to the main shear stresses of the covering. Case C is then favourably applied by determining P_o and P_u in addition to the moment. If a knowledge of the moment, however, is sufficient, the simply statically indeterminate computation of case D will yield useful approximate values.

TABLE VI.

Horizontal Components P_o and P_u of Flange Forces of Ribs 2 and 3 at Centre Spar and Moment M_h of Rear Tubes in Antisymmetrical Case W_2.

Case.	P_o / P_u	M_h	P_o / P_u	M_h	P_o / P_u	M_h
1	± 579.5 / $+352.4$	0.323 M_2	± 550.5 / $+267.2$	0.284 M_2	± 566.7 / $+287.4$	0.296 M_2
4	± 104.2 / ∓ 85.7	0.066 M_2	± 101.3 / ∓ 68.2	0.059 M_2	± 104.8 / ∓ 75.6	0.063 M_2

In loading case W_3 (Fig. 3*d*), M_2 was chosen equal to 1,000 kgm. The assumptions of loading case W_1 (Table 2) were also investigated with the exception of cases 2, 3, and D. The shears of the covering and the spar webs and the flange forces of the spars are given in Tables V*a*, *b*. The forces P_o and P_u are given in Table VI, which also gives the moment M_h computed from

$$\frac{P_o + P_u}{2} h.$$

Only rough approximations are obtained since $P_o \neq P_u$ and therefore in the rear tubes no pure torsion moment is applied. As in the loading case W_1, there here also appears a large dependence of the forces P_o and P_u and hence the moment M_h on the stiffness of the flanges in the rear part of ribs 2 and 3. For rigid flanges (case 1), $P_o = \pm 579.5$ kg., $P_u = \mp 352.4$ kg. (case A, complete restraint against deformation) and $P_o = \pm 550.5$ kg., $P_u = \mp 267.2$ kg. (case B, no restraint) and for elastic flanges (case 4) $P_o = \pm 104.2$ kg., $P_u = \mp 85.7$ kg., and $P_o = \pm 101.3$ kg. and $P_u = \mp 68.2$ kg., respectively. From these values, it may be seen that in loading case W_2, the restraint against deformation at ribs 1 and 4 leads to a relatively greater change in the forces P_o and P_u and hence in the effect of the rear tubes than in loading case W_1. The fourfold, statically indeterminate case B (no restraint against deformation) still gives sufficiently accurate values, since there will generally be no complete restraint and loading case W_3 is much less important than case W_1 for the total force distribution. The further reduction of the static indeterminates in case C (threefold statically indeterminate) by neglecting the deformation forces in the front tubes leads to useful approximate results for P_o and P_u and for the shears of the covering and spar webs.

V. SUMMARY.

It is shown that the force distribution resulting from incomplete ribs in single spar wing structures may be determined with the aid of shear field method by a statically indeterminate computation. A numerical computation is given of the force distribution of a wing structure whose two neighbouring incomplete ribs with web missing in half the section are torsionally loaded. In spite of the

incomplete ribs, there is obtained a distribution of the applied forces over the entire wing cross section which depends considerably on the stiffness of the ribs, particularly of the flanges in the rear part of the tubes and of the manner of application of the forces on the rib. Through the use of simplifying assumptions, it is possible to reduce the number of static redundancies and thus the computation work without introducing much error in the results. If two equal and opposite moments are applied at the incomplete ribs, a onefold statically indeterminate computation is already sufficient for obtaining a useful approximate value of the moment contribution of the rear tubes.

REFERENCES.

1. Ebner, H., and Köller, H. Über den Kraftverlauf in querversteiften Scheiben. Luftfahrtforschung, Vol. 15, No. 10-11, Oct. 10, 1938, pp. 527-542.
2. Ebner, H., and Köller, H. Über die Kräfteumlagerung in mehrholmigen Flügeltragwerken bei Ausfall einzelner Bauteile. Jahrbuch 1938 der deutschen Luftfahrtforschung, pp. I 452-456.
3. Köller, H. Einfluss von Steifigkeitsänderungen auf den Kraftverlauf in statisch unbestimmten Tragwerken. Jahrbuch 1938 der deutschen Luftfahrtforschung, pp. I 444-451.
4. Hertel, H. Die Verdrehsteifigkeit von Flugzeugbauteilen. Jahrbuch 1931 der deutschen Versuchsanstalt für Luftfahrt, p. 189.
5. Heck, O. S. Über die Berechnung versteifter Scheiben und Schalen. Jahrbuch 1937 der deutschen Luftfahrtforschung, pp. I 442-451.

REVIEWS.

Internal Combustion Engineering.

Revised and edited by A. T. J. Kersey, A.R.C.Sc., M.I.Mech.E., M.I.A.E., F.Inst. Fuel. Blackie and Son, Ltd. 1940. 17/6 net.

This is a new and partly rewritten edition of a work originally published some years ago. The last decade has seen considerable changes in the design and construction of the internal combustion engine, that any book not dealing with fundamental principles of construction and theory would be bound to be dated.

The book under review lays emphasis on firm fundamental principles governing changes and improvements in design and the trend of future developments is indicated.

The first section, written by G. A. Burls, M.Inst.C.E., and revised by the editor, is concerned with gas engines, the fuels used for them, methods of ignition, starting, cooling, lubrication and descriptions of typical engines. The greatly increased efficiency of the modern oil engine has put the gas engine in the background for many purposes, especially in the smaller horse-powers.

Gas Producers, by the same two authors, forms the subject of the next section. In this section, of interest at the present time, is a description of portable gas producers for road vehicles, producers much more widely used on the continent than in this country. The authors draw the conclusion that the experience of the special trailers fitted with gas producers now being used may lead to the production of road vehicles specially designed for producer gas, although it is admitted that there are certain difficulties still to be overcome. A short section on the Operation of Gas Engines, by P. R. Allen, A.M.Inst.C.E., follows and completes that part of the book dealing with this subject.

Oil Engines (including marine oil engines), by J. Richardson, B.Sc., M.Inst.C.E., and G. A. Burls, M.Inst.C.E., begins the more important part of the work under review. Considerable attention is paid in this section to the Diesel engine and its development for all purposes, and large marine engines. The first part of this section is followed by chapters on the operation of oil engines and oil engines for road vehicles, both by A. T. J. Kersey. It is remarkable to note that the heavy oil engine was not used on British roads until 1929. In eleven years, however, it has almost replaced the petrol engine for heavy commercial vehicles.

The last section is the one of chief interest to the aeronautical engineer. By A. T. J. Kersey, it deals with Aero Engines. Occupying some sixty pages it does not pretend to be more than an outline of the various types of engines which have been developed in aviation. A considerable part of this section is descriptive.

For those who wish to have a book which gives a general survey of the construction, application and operation of all classes of internal combustion engines, this book can be recommended.

Squadrons Up!

Noel Monks. Victor Gollancz, Ltd. 1940. 12/6 net.

Mr. Noel Monks had the great advantage of being the *Daily Mail* war correspondent with the Royal Air Force in France and here tells the story of the two R.A.F. fighter squadrons attached to the Advanced Air Striking Force in France from September, 1939, until the eve of France's capitulation in June, 1940.

It is a vivid unsatisfying story, vivid because the author knows how to present his material and unsatisfying because the censor has clearly not released much which the author would have told.

The story begins with an account of the circumstances of the death of Flying Officer E. J. (Cobber) Kain, D.F.C., killed, as so many have been killed, by stunting too near the ground in a few moments of exhilaration of spirits.

" When France laid down her arms and Squadrons 1 and 73 flew back to England, of the thirty officer pilots who had flown out to France nine months before, twenty-six were still alive and ready to carry on from home bases.

" Over an area of 200 miles in France the wreckage of 300 German aircraft of all types lay strewn. They were the Hurricanes' victims, the official bag of Squadrons 1 and 73. At least another 100 staggered toward their bases in Germany, but never reached there. Probably thirty Hurricanes were wiped off in combat, forced landings, and mishaps."

" If they never fight another battle in this war, the officer pilots and N.C.O. pilots of 1 and 73 Squadrons will have done their share."

With that no one will disagree.

There are too many good stories in this book to spoil it by quoting them. Here is the story of the destruction of Maastricht Bridge; of Jeannette who ended her life before a firing squad; of Rheims, " spree town "; of " Cobber " Kain and of the Prisoner of Luxemburg, the young pilot who looked sixteen but was " going on for twenty-one."

This book is a first-hand account of the first fighting in the air, a story which when told in its entirety will be the most astonishing story of courage, determination, and outstanding ability the world has ever known in all its war history.

FLIGHT HANDBOOK (2nd Edition).

W. O. Manning, F.R.Ae.S., and the Technical Staff of *Flight*. Flight Publishing Co., Ltd. 1941. 4/- net.

The first edition of this excellent little manual was published in 1938. This edition has been completely revised and enlarged. The thoroughness of the revision is evident from the change in Fig. 1, showing variation of temperature with height, to Fig. 115, showing refuelling in the air.

To the first chapter on First Principles there has been added in this new edition a number of pages on the difference between civil and military aircraft. In the following chapter the letterpress on Drag has been re-written and the benefits of shaft drives and ducted cooling explained. The chapter on Aircraft Structures has been considerably re-written and a description added of geodetic construction, retractable floats and three-wheeled undercarriages. Even the chapter on Balloons and Airships receives its addition, due to the war, by the barrage balloon. The chapter on Airscrews has been added, explanations of controllable pitch and feathering airscrews, and a considerable amount of matter has been added to the Instrument chapter.

The handbook finishes with a new chapter on Modern Developments, beginning with Plastics. In this chapter, too, such modern developments as pressure cabins, diving brakes, radio-controlled aircraft, prevention of icing and the assisted take-off are explained.

For those who wish to get a general and sound idea of the aeroplane, how it flies and how it is constructed, this is one of the first books they should have. It is simply and well written and dives just deeply enough, and not too deeply, into the things which matter.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES

APRIL, 1941.

New Council for 1941-1943.

President:

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Past-President:

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Mr. N. E. Rowe, B.Sc., A.C.G.I., D.I.C., A.F.R.Ae.S.
Mr. F. M. Thomas, A.F.R.Ae.S.
Mr. A. Hessell Tiltman, B.Sc., F.R.Ae.S.
Dr. H. C. Watts, M.B.E., M.Inst.C.E., F.R.Ae.S.
Mr. R. T. Youngman, B.Sc., F.R.Ae.S.

NOTE.—The President and Vice-Presidents are elected in May or June and take office in October.

Wilbur Wright Memorial Lecture.

The 29th Wilbur Wright Memorial Lecture will be given by Mr. J. T. Trippe, M.A., President, Pan American Airways Inc., on Thursday, May 15th, at 6.30 p.m., in the Lecture Theatre of the Institution of Electrical Engineers, Victoria Embankment, W.C.2. The subject of the lecture will be "Ocean Air Transport."

Meeting of Council.

A Meeting of Council was held in the Offices of the Society on February 19th, 1941.

Present: Mr. A. H. R. Fedden (Past-President) in the chair; Captain P. D. Acland, Mr. R. Blackburn, Dr. H. Roxbee Cox, Professor F. T. Hill, Mr. J. E. Hodgson (Honorary Librarian), Captain A. G. Lamplugh, Lieut.-Col J. T. C. Moore-Brabazon, Mr. D. R. Pye, Major B. W. Shilson, Mr. F. M. Thomas, Mr. A. Hessell Tiltman, Dr. H. C. Watts, Mr. L. A. Wingfield (Solicitor), Mr. R. T. Youngman.

Among the business discussed was the following:—Deputation to the Secretary of State for Air; Election of Fellows and Associate Fellows; Joint Letter to the Prime Minister; Technical Instruction for Engineers temporarily serving in H.M. Forces; Annual Report of the Council for 1940; Wilbur Wright Memorial Lecture, 1941.

Election of Members.

Fellows.—Archibald Graham Forsyth (from Associate Fellow), Henri-Marie Jullerot, Robert McLean (from Companion).

Associate Fellows.—Arthur Roderick Collar, Andrew William Henry Dalrymple (from Student), Geoffrey Dean Dawson (from Graduate), Leopold Frommer, Kenneth Alfred John Knell (from Student), Robert Knight Page (from Graduate), John George Magrath Pardoe (from Graduate), Eric Frederick Priest, William George Savory (from Student), Harry Methuen Schofield, George James Smith-Pert, Frederick James Alexander Thompson (from Student).

Associates.—Norman Alexander Adler, Richard Ewart Garner, Harold Hurlin, Stuart Maxwell Kirkcaldie, Sidney James Noel-Brown, Gordon Ernest Rose (from Student), Leslie Clarence Thomsett, Charles Frank Wake, Harold Cuthbert Webster, William Glanville Woodward.

Graduates.—John Raymond Batty (from Student), Brian Stewart Eamer Beattie, Reginald Raffles Ashley Bratt, Benjamin Elliott, Frank Grinsted, Geoffrey James Barnard Hall (from Student), John Arthur Jacobs, Arthur Charles Samuel Pindar, Cecil Harry Shaw, Richard Stallebrass (from Student).

Students.—John Wilkes Ames, Eric Donald Bailey, Maurice Edward Burt, David Dunbar Carrow, James Cuthbert Barrington Coleman, Peter Kenneth Cowan, Edward Albert Langridge, Kenneth William Norris, John Gordon Roxburgh, Kenneth William Speller, Douglas Hunt Turner, Robert Michael Wingate.

Companions.—Bernard Joseph Gregoire Ledeux.

Associate Fellowship Examinations.

The next Associate Fellowship Examinations will be held on Wednesday, May 21st, and Thursday, May 22nd, 1941, and the Library will be closed on those days. Full particulars will be sent direct to candidates who have entered for the examination.

Income Tax.

In response to numerous inquiries with regard to a rebate on Income Tax for their subscriptions, the following is a copy of a letter received from the Principal Inspector of Taxes:—

" Ref. H.R.S. 34/C.I. 4420/63. 18/8/28.

Dear Sir,—Further to your interview with Mr Stonely at this office on the 19th July, I am now in a position to inform you that the Board of

Inland Revenue will not raise objection to the allowance as an expense for Income Tax purposes of annual subscriptions paid by members who are:—

(i) Assessable under Schedule D of the Income Tax Acts in respect of professional or trading profits, subject to the decision of the Commissioners who make the assessment that such subscriptions are sufficiently closely related to the business carried on; or

(ii) Assessable under Schedule E in those cases only in which continual membership of the Society is an essential condition of the terms of appointment.

Yours faithfully,

(Signed) GEO. WILCOCK,

Principal Inspector of Taxes."

Additions to the Library.

Pamphlets in italics, with location reference following in brackets
Books marked * or ** are not available for loan.

A.a.218.—Elementary Aerodynamics. By D. C. M. Hume. Pitman (Canada), Ltd. 1941.

*B.g.98.—Aircraft Recognition. By R. Saville-Sneath. Penguin Books. 1941. 6d.

*G.b.3.—*British Standards Institution: Sectional List of British Standards: Aircraft Materials and Components. (Jan., 1941.)* Also corrigenda and war emergency revision slips to the following specifications:—3B.11, 2D.27-31, 4K.6, 3F.15, 3F.32, 3F.33, 2SP.1, 5V3, 2X.17; and addenda to 2B.8 and 2SP.3. (File Case.)

*G.b.28.—*Ministry of Aircraft Production: List of Material Specifications, D.T.D. Series. (Sept., 1940.)* Also the following Specifications:—Nos. 391, 392, 394, 395, 398, 399, 400, 401, 402, 403, 404, 406A, 407, 408, 410, 411, 412, 413, 416, 417, 418, 420, 421, 422, 423A, 424, 426, 427, 428, 429, 431, 436, 437, 440, 441, 442, 443, 448, 449, 450, 460, 501, 507, 535. (Y.19.)

*G.b.34.—Specifications for Aluminium and Aluminium Alloy Products. Northern Aluminium Co. 1940.

*G.b.35.—Noral Handbook, Section E: Castings. Northern Aluminium Co. 1939.

G.e.A.61-71.—*Sales Engineering Bulletins and Research and Development Bulletins of the Northern Aluminium Company, Ltd.*

Gravity Die Castings in Aluminium Alloys. (Undated.)
Casting Alloy N.A. 226. 1937.
NA. 350 Alloy. 1938.
Applications of "Noral" Aluminium Alloys to Shipbuilding and Marine Engineering. 1938.
Gravity Die Castings in NA. 226 Aluminium Alloy. 1938.
Protection of Aluminium Alloys during Storage. 1938.
Mechanical Properties, Uses and Manipulation of Aluminium Alloys. By F. R. C. Smith. 1939.
Machining of Aluminium Alloys. 1940. (Two copies.)
Cold Forming of High-Strength Aluminium Alloy Sheet. 1941. (Two copies.)

G.e.K.8.—Noral Paste for Paint. Northern Aluminium Co. 1937.

G.f.21.—The Welding and Riveting of Aluminium (2nd Ed.). Northern Aluminium Co. 1938.

I.c.16.—Waves: a Mathematical Account of the Common Types of Wave Motion. By C. A. Coulson. Oliver and Boyd. 1941. 5/-.

N.b.6.—*Exhaust Noise and Other Noises of Motor Transport. By Wing Com. T. R. Cave-Browne-Cave. Journal of the Royal Society of Arts, June 28*, 1935. (PN.1.c.1.)

*Q.a.68.—Consolidated List of Government Publications, 1939. H.M.S.O. 1940. 1/-.

**R.b.214.—Particulars of the Balloon Ascent with Lieut.-Col. Thorneycroft and Capt. Morton at Molineux Ground, Wolverhampton, Sept. 11, 1882. Privately printed, 1882.

**R.f.68.—Aeronautics in the Union and Confederate Armies, with a Survey of Military Aeronautics prior to 1861. By E. Stansbury Haydon. John Hopkins Press, Baltimore, U.S.A. 1941. $4.00.

S.a.119.—Zeppelins and Super-Zeppelins. By R. P. Hearne. The Bodley Head. 1916.

S.a.120.—*The War Aims of the British People: a Manifesto issued by the British Labour Party. Hodder and Stoughton.* 1917. 1d. (PS.1/21a.)

*S.b.98.—*Air Force Memorandum No. 1: Transfer of the R.N.A.S. and R.F.C. to the R.A.F. Harrison and Sons.* 1918. (Y.27.i.a.2a.)

S.e.17.—*The Military Aeroplane. By E. Colston Shepherd. Oxford University Press. (Oxford Pamphlets on World Affairs, No. 44.)* 1941. 3d. (PS.3.a.8.)

*S.e.18.—*The Fire-Party's Handbook. By R. F. Reynolds, R. D. Wormald and J. M. Young. Jordan and Sons (Chancery Lane, W.C.2).* 1941. 6d. (PS.3.b.6.)

*S.e.19.—I Saw London Take It. (Commentary for American documentary film.) By Quentin Reynolds. Crowell-Collier Pub. Co., U.S.A. 1941.

S.e.20.—*The Value of Air Power. By F. A. de V. Robertson. Article in "Nineteenth Century," Feb.*, 1941. (PS.3.a.9.)

*T.a.84.—*Sydney Camm, Creator of the Hawker Hurricane. By G. Edwards. (Cutting from "News-Chronicle," Feb. 18th*, 1941.) (Y.5.C.)

T.b.74.—*Pioneer Flying on the Cape Route. By Mrs. D. Bentley. Article in "London Calling" (B.B.C. Overseas Journal), Feb. 27th*, 1941. (Y.11.iv.a.22.)

UL.7.—Science Reports of the National Tsing-Hua University, China. Series A, Vol. IV, Nos. 2-3. 1940.

*UU.c.—*National Advisory Committee for Aeronautics: Technical Memoranda.*

No. 951. Variation in Velocity Profile with Change in Surface Roughness of Boundary. By W. Jacobs. (From Z.A.M.M., April, 1939.)

No. 952. Standards for Discharge Measurement with Standardised Nozzles and Orifices. (German Industrial Standard, No. 1952.)

No. 953. Pressure and Temperature Measurement in Supercharger Investigations. By A. Franz. (From Jahrbuch 1938 der Deutschen Luftfahrtforschung.)

No. 954. Limits of Single-Stage Compression in Centrifugal Superchargers for Aircraft. By K. Kollmann. (From Luftwissen, March, 1940.)

*UU.f.—*National Advisory Committee for Aeronautics: Miscellaneous Papers.*

No. 45. Armament of Enemy (*i.e.*, English and French) Aircraft. By Joachim Beseler. (From Luftwissen, March, 1940.)

V.2/13.—Chartered Institute of Patent Agents: Transactions, Vol. LVIII, Session 1939-40.

Y.22.—*Guggenheim Aeronautics Laboratory, Pasadena, U.S.A.: Publications.*

No. 119. The Growth of the Circulation of an Airfoil Flying Through a Gust. By W. R. Sears and A. M. Kuethe.

No. 120. Two-Dimensional Subsonic Flow of Compressible Fluids. By Hsue-Shen Tsien.

No. 121. General Airplane Performance. By W. C. Rockefeller. (N.A.C.A. Report No. 654.)

No. 122. The Aerodynamics of Reacting Substances. By H. Bateman.

No. 123. The Buckling of Spherical Shells by External Pressure. By Th. v. Karman and H. S. Tsien.

No. 124. The Influence of Running Propellers on Airplane Characteristics. By Clark B. Millikan.

No. 125. Some Remarks on Mathematics from the Engineer's Viewpoint. By Th. v. Karman.

No. 126. Some Mechanical Tests on Aluminium Alloys 14S-T and 24S-T. By W. B. Mechling and S. S. Jack.

No. 127. An Investigation of Sheet-Stiffener Panels. By Louis G. Dunn. (N.A.C.A. Tech. Note 752.)

No. 128. The Influence of Curvature on the Buckling Characteristics of Structures. By Th. v. Karman, Louis G. Dunn and H. S. Tsien.

No. 129. Operational Methods in the Theory of Airfoils in Non-Uniform Motion. By Wm. R. Sears.

No. 130. Boundary Layer and Wake Survey Measurements in Flight and in the Wind Tunnel. L. B. Rumph and R. Schairer.

No. 131. The Engineer Grapples with Non-Linear Problems. By Th. v. Karman.

J. Laurence Pritchard, *Secretary and Editor.*

DESCRIPTION OF A WATER TUNNEL AND APPARATUS FOR THE INVESTIGATION OF FLOW PROBLEMS.

By A. Fage, F.R.Ae.S., A.R.C.S.,

and

J. H. Preston, B.Sc., Ph.D., A.F.R.Ae.S.

Abstract.

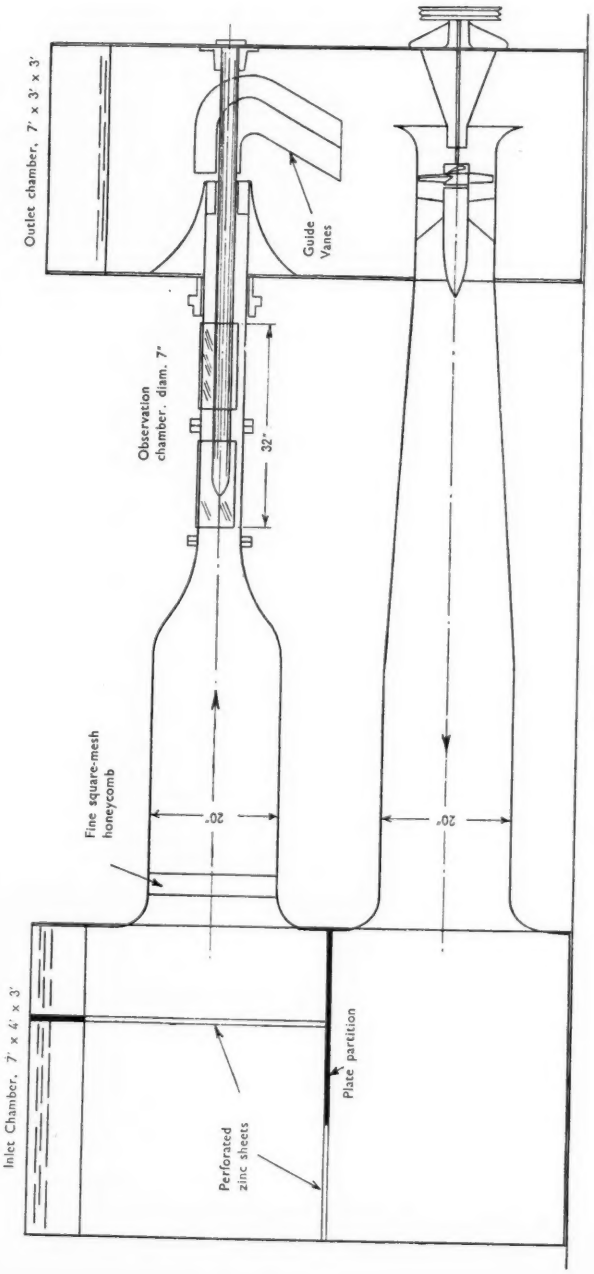
The water tunnel, closed-return type, described in the paper is especially suitable for the observation of flow near the surface of a long streamline body of revolution at Reynolds numbers up to 1.3×10^6. The observation chamber is 32 ins. long and it has a circular cross-section of diameter 7 ins. The stream in the observation chamber although slightly disturbed at the higher speeds of flow is substantially free from turbulence (except near the wall) at all speeds and throughout its entire length.

The tunnel is equipped with two instruments designed for flow observation. The first instrument, named fluid-motion microscope, allows the movements of small particles in a bright beam of light to be observed and measured. This instrument is suitable for the study of details of flow too small to be seen with the unaided eye, but which are revealed under a microscope at a medium magnification. The second instrument, the fluid-motion microscope with an interrupter, allows the speed of a particle to be determined from a measurement of the length of its track recorded for a known time of exposure on a photographic plate. This instrument can be used to measure the velocity distribution in a boundary layer to a distance of about four thousandths of an inch from the surface.

Water Tunnel.

1. Experimental investigations on problems of fluid motion which depend on the visual observation of the movement of particles in the fluid are more conveniently made in water than in air, for particles move appreciably slower in water than in air (about one-thirteenth) for the same flow pattern given by the same model, and the choice of particles suitable for observation in water is less restricted than it is for air. When the investigation is concerned with the flow in the neighbourhood of a body the conditions of the investigation are, in general, under more favourable control when the observation is made for the body held in the stream of a tunnel than when the body is moved through a stationary fluid; and if a water tunnel is used the same Reynolds number for the same body can be obtained for an expenditure of about one-third of the horse-power needed for a wind tunnel of the same size and shape. The utility of a tunnel is enhanced if its stream is substantially free from turbulence for then observation of flow can be made for a body either in the free stream of the tunnel, or in a stream into which turbulence of known intensity and scale is introduced by a grid placed across the stream upstream of the body. The water tunnel* now to be described was designed for observation of flow, and incorporates those features which are known to be favourable to the production of a steady stream.

* The water tunnel and its apparatus were designed and constructed in the Aerodynamics Department of The National Physical Laboratory, and descriptions are published on the recommendation of the Aeronautical Research Committee and by permission of the Director of the Laboratory. An account of work made on the tunnel, on transition from laminar to turbulent flow in the boundary layer of a streamline body, will shortly be published in Proceedings of The Royal Society, Vol. 178, A.



Water Tunnel (Elevation).

FIG. 1.

2. Fig. 1 gives a sketch of the water tunnel, and Fig. 2 a photograph of the tunnel and its apparatus. The tunnel is of the closed-return type, and it is particularly suitable for observation of flow near the surface of long streamline bodies of revolution. The observation chamber is 32 ins. long and has a circular cross-section of diameter 7 ins. Two semi-circular perspex windows are fitted into the steel castings which form the observation chamber. Astigmatic distortion of view due to the cylindrical curvature of a window is eliminated by enclosing each window in a water cell having a vertical glass wall and a free water surface. The water during its passage from the inlet chamber to the observation chamber flows through a fine mesh honeycomb, constructed of thin-wall square tubes (3 ins. long and $\frac{3}{8}$ in. wide) soldered together at the corners, a settling chamber 32 ins. long and 20 ins. diameter, and an entrance nozzle contracting in diameter from 20 ins. to 7 ins. The honeycomb straightens the flow and reduces both the scale and intensity of the disturbances in the inflowing stream, the settling chamber gives the water time to dissipate the turbulent energy of the smaller eddies by the action of viscosity, and the contraction of flow in the entrance nozzle reduces the fractional intensity of turbulence. As the

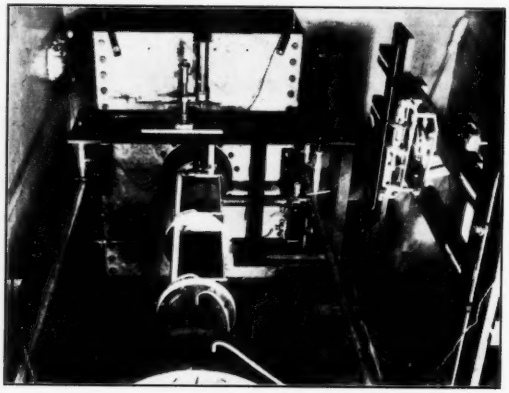


FIG. 2.
Water tunnel and apparatus.

water flows out of the observation chamber it is deflected downwards by vanes in the outlet chamber and then returns to the inlet chamber through a divergent duct having a circular cross-section increasing in diameter from 12.5 ins. to 20 ins. over a length of about 5 ft. The average speed of flow through the inlet chamber is low (less than 0.12 ft./sec.), and unevenness in this flow is smoothed out by horizontal and vertical baffles of perforated zinc plates. The water is circulated by a four-bladed screw housed in the return duct. The diameter of the screw is 12 ins., and its boss is shrouded by a streamline fairing. The blades of the screw have a constant aerofoil section (flat under-surface, 3 ins. chord, 0.39 in. maximum thickness). The blade angles decreased from 17° at 2 ins. radius (boss) to 7° at 6 ins. radius (tip). The blade angle at the middle section (radius 4 ins.) is 9.5°. Six symmetrically-arranged radial straightening vanes formed of symmetrical aerofoils increasing in chord from 2 ins. at 2 ins. radius to 6 ins. at 6 ins. radius are mounted, at 0° incidence, in the return duct just behind the screw. The screw shaft runs in tufnol bearings housed in a stiff conical casting supported on the inside of the outer wall of the outlet chamber. The screw is belt driven by a $\frac{1}{2}$ h.p. D.C. electric motor outside the tunnel. The motor speed is regulated by potentiometer control on a 100-volt battery

supply. Stroboscope discs mounted on the screw shaft outside the tunnel and viewed by a Neon lamp on 50-cycle A.C. mains are used to measure the screw speed and to indicate steady running conditions.

3. The general character of the flow in the observation chamber can be indicated by the behaviour of fine filament bands. Bands of photographic white ink issuing into the stream from a fine bore tube were used, the speed of efflux of the jet being adjusted to be about the same as the local speed of the stream. This condition is easily obtained, for if the speed at which the jet issues is too low the band is too fine for observation; and if the speed is too high the jet issues as a turbulent stream which rapidly diffuses and disappears. Interference flow from the tube itself can influence the behaviour of the jet, but such effects are negligible if the tube is mounted with its mouth in the entry to the con-

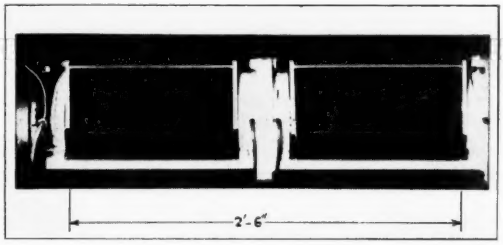


FIG. 3.
Tunnel flow (a).
Steady filament, $V < 1.6$ ft./sec.

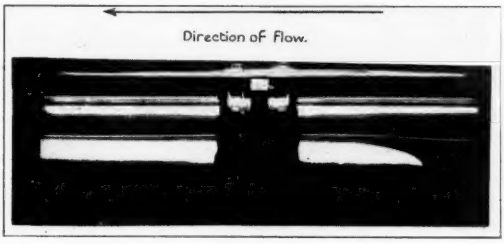


FIG. 4.
Flow near body (a).
Steady filament, $V < 1.6$ ft./sec.

tracting nozzle of the tunnel. The particles in the photographic white ink were very minute, and the behaviour of a filament band issuing from a fine bore tube could be taken to be representative of that of a filament line. Photographs of filament bands in the observation chamber taken on Ilford H.P.2 (F) Hypersensitive Panchromatic Film are given in Figs. 3 and 4. The filament bands were photographed against a dark background, and this condition was obtained by illuminating them by a narrow beam of light at right angles to the axis of the camera, by screening all extraneous light and reflections, and by taking care that the tunnel windows and camera lenses were clean. If such precautions are taken, and if fast plates are used, photography of filament bands is possible without exceptionally intense illumination (a 1,000 watt projection lamp is satisfactory).

In a steady rectilinear stream, a filament band flows steadily downstream without any change in cross-section, apart from the imperceptible growth arising from molecular diffusion. Filament bands in the stream flowing through the observation chamber behave in this manner (except near the wall) over the entire length of the chamber (32 ins.) at all speeds up to about 1.6 ft./sec. (Fig. 3). Above this speed, and up to the highest speed of flow (about 7 ft./sec.), a filament band waves spasmodically with an amplitude increasing with the downstream distance, and with a frequency increasing with the velocity of the stream, but there is no tendency for the filament to break down or to lose its identity. A filament band at the wall begins to wave at a lower stream speed (about 1.1 ft./sec.) than that for a band at some distance from the wall, and, at high speeds, the tail of a band breaks down, diffuses rapidly and eventually disappears. The boundary layer at the tunnel wall is therefore turbulent at high speeds, and simultaneous observation of two filaments, one at the wall and the other well within the stream, suggests that the waviness of the filament in the stream is associated with the breakdown of flow in the boundary layer at the wall.

It was observed that filament bands on the surface of a long streamline body of revolution were steady over the entire length of the body under observation (26 ins.) at all speeds up to the maximum speed of the tunnel (7 ft./sec.); and filament bands near and just outside the boundary layer were steady up to 1.6 ft./sec., and slightly wavy from this speed to the highest speed of the tunnel (Fig. 4). The kinematic viscosity of the water at the time of observation was 11.46×10^{-6} ft.^{2}/sec., so that the flow in the boundary layer of the body was laminar up to a Reynolds number, $U_0 X/\nu$, about 1.3×10^6, where U_0 is the stream velocity, and X is the axial distance from the nose. The general conclusion to be drawn from the observations of the behaviour of filament bands is that the stream in the observation chamber although slightly disturbed at the higher speeds is substantially free from turbulence at all speeds and throughout its entire length, except at the wall.

Apparatus.

(i) Fluid-Motion Microscope.

4. A fluid-motion microscope is an instrument which allows the movements of small particles in a beam of light to be studied, and is especially suitable for the observation and measurement of details of flow too small to be seen with the unaided eye, but which are revealed under a microscope at a medium magnification. The fluid-motion microscope now to be described was constructed specially for use with the water tunnel, and was designed in the light of experience gained from apparatus of the same kind, then known as an ultramicroscope, used in earlier work.* The name fluid-motion microscope, now introduced is considered to be more appropriate than the name ultramicroscope used formerly. Strictly speaking, an ultramicroscope is an instrument, or rather a special illumination system used with an ordinary microscope, for the study of the Brownian movements in a fluid, and its method of working depends on the fact that particles whose size is smaller than the wave length of light can be seen under a microscope by the light they scatter as they move through an intensely bright beam of light. The present apparatus resembles an ultramicroscope in so far as the motions of particles moving through a bright beam of light are observed under a microscope, but the size of the observed particles (0.0015 in.) is many times greater than the wave length of light, and the speeds with which they move are appreciably greater, except very near a surface, than those which reveal the Brownian movements. Further, the technique of velocity measurement with the present apparatus bears no resemblance to that with an ultramicroscope.

* Fage and Townend. Proc. Roy. Soc., A, Vol. 135, 1932, pp. 656-684. Fage. Phil. Mag., Vol. 21, 1936, pp. 80-105.

Direct observation of the field of flow in the tunnel is not possible with the magnification used (about 40), except near the wall, so a field lens is used to produce outside the tunnel an image of the field, and this image is viewed under the microscope (Fig. 5). The field lens is a combination of two Stepnite binocular object glasses, each of diameter 2.04 ins. and focal length 6.61 ins., mounted

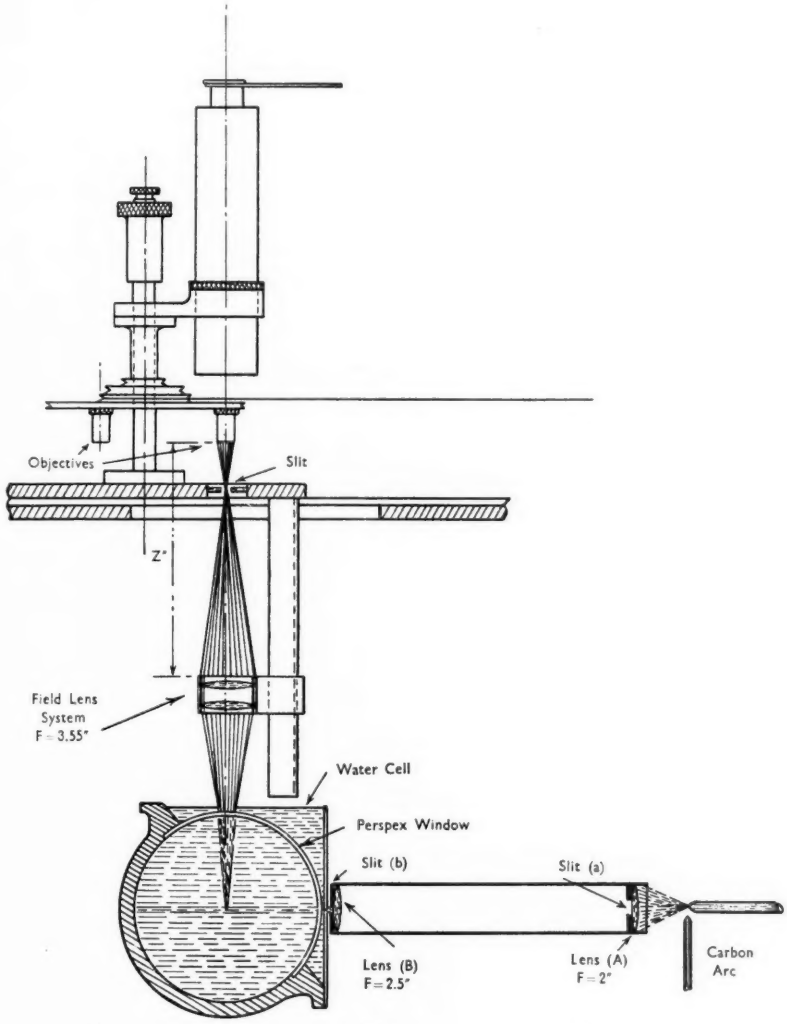


FIG. 5.

with a small clearance in a cell. The focal length of the combination is 3.55 ins. The field lens is mounted with its optical axis coincident with that of the microscope; and the distance between the field lens and the microscope is adjustable, the field lens being carried on a vertical slide rigidly attached to a horizontal table carrying the microscope. The field lens works at a magnification about

1 : 1. The table carrying the optical system can be traversed parallel to and also at right angles to the axis of the observation chamber.

5. The field of flow is illuminated by a horizontal beam of light at right angles to the axis of the microscope system. For a given light source, the most intense illumination is obtained when the light is focussed by a single spherical lens of large aperture. This simple light beam is not satisfactory when a carbon arc is used as the light source, for the cross-section of the beam at the point of observation is circular and tends to be too small, and the background too bright, for reliable measurement of speed.

A better shape of light beam is one having a rectangular cross-section. The most suitable dimensions of the cross-section depend on the lens system used; and for the present apparatus a rectangular section of width 0.40 in. and depth 0.15 in. is satisfactory. The system used is illustrated in Fig. 5. Light from the circular crater of a 5 amp. carbon arc is focussed by a spherical convex lens A ($f=2$ ins., $D=1.375$ ins.) on the plane of lens B ($f=2.5$ ins., $D=1.375$ ins.) and passes through a rectangular slit, b, 0.4 in. $\times$ 0.15 in. Mounted at lens A is a rectangular slit, a, whose dimensions are such that a rectangular image, 0.4 in. $\times$ 0.15 in., is given at the point of observation by the lens B. The brightness of a carbon arc depends appreciably on the relative positions of the two carbons, and to obtain the brightest beam it is essential that as the carbons burn they are maintained in their correct relative positions, with the vertical carbon close to and just below the crater of the horizontal carbon, and that the horizontal carbon is mounted so that its crater is on the axis of the system. To meet these conditions, a specially designed arc lamp with stiff carbon carriers and capable of fine adjustment was used.

6. There is an optimum size and number of particles which give, for a given brightness of illumination, the best condition for observation. If the particles are too small the light they scatter may not be sufficient to allow them to appear as bright points of light; and if the particles are too large they may not faithfully represent the internal motions of the flow, if the scale of these motions is small. The best condition is obtained when particles are viewed against a dark background; and if too many particles are present the diffused light scattered from them gives a background too bright for sharp contrast. The most suitable particles for observation were found to be those from fine aluminium powder, sifted to obtain a fairly uniform size. Powder from Fine Flitters (English Metal Powder Company, Ltd.) was run successively through 100, 120, 200 and 240 B.S.S. copper gauzes and well shaken in water, and the particles remaining in suspension after the water had stood several hours were used. The average size of these particles was about 0.0015 in.

Drops obtained from a spray of a mixture of olive oil and ethylene di-bromide having the density of water were tried. They give sharp points of light when brightly illuminated, but are not suitable for use in the water tunnel because they soon break up and collect on and smear the window. Experiments were also made with aerated water, but without success, for the small air bubbles suitable for observation either rose to the surface or were rapidly absorbed in the water.

With the magnification used (about 40 : 1) the actual length of particle tracks in the field of view is about 0.12 in. In laminar flow, the tracks are parallel; in turbulent flow, they continually change direction and appear, owing to persistence of vision, to be crossing one another.

7. The principle of velocity measurement with the fluid-motion microscope depends on the fact that a particle appears to be stationary when viewed through an instrument moving at the same speed, and as a streak, when viewed at a different speed. Movement of the entire microscope is not necessary for relative movement can be simulated by movement of the objective alone, the tube and eyepiece remaining fixed. The method of working is illustrated in the diagrammatic sketch of Fig. 5, and the photograph of Fig. 6. The microscope

objective is carried on a horizontal disc which rotates about an axis parallel to and offset from the tube axis, and once in each revolution the optical axes of the objective and the eyepiece are brought into coincidence, the alignment of the apparatus being such that when this coincidence occurs the objective is moving in the mean direction of the stream. The speed of a particle brought to apparent rest is given by the product of the measured rotational speed of the objective and a calibration factor, whose value depends on the optical system. This factor is determined directly by relating linear displacements in the field of observation, read on a scale aligned with its edge in the direction of flow, with angular displacements of the disc carrying the objective through which the scale is viewed. The field of flow is visible for only a small part of each revolution, and the time interval between successive views is shortened by mounting three identical objectives (Watson 2 in. parachromatic objectives) on the rotating disc.

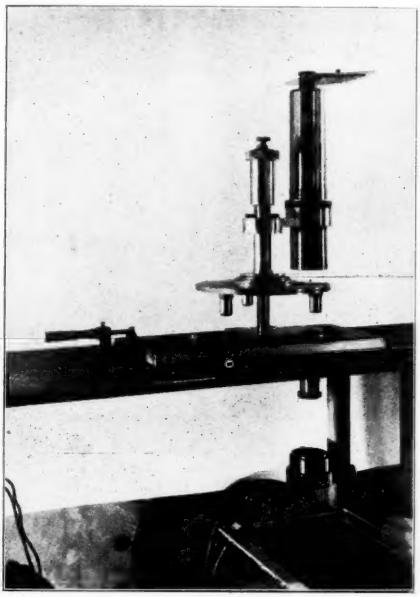


FIG. 6.
Fluid-motion microscope.

When the objective disc rotates at the speed corresponding to the mean speed of flow, views of steady rectilinear motion show groups of points, or more precisely, groups of short cross-stream streaks, since there is a small cross-stream component of velocity arising from the curvature of the path of the objective; and views of turbulent motion show streaks, whose length and direction change with the view. For turbulent motion, bright points and short cross-stream streaks are seen only when the objective rotates at a speed lying within the rotational speeds corresponding to the maximum and minimum speeds of flow at the point of observation; and the maximum speed at the point is determined from the highest rotational speed, and the minimum speed from the lowest rotational speed, for which points or short cross-stream streaks are seen. Experience has shown that the mean speed of flow can be taken with good accuracy to be the mean of the maximum and minimum speeds. The maximum

value of the downstream component of turbulent velocity is one-half the difference between the maximum and minimum speeds. In practice, the rotational speed of the microscope disc is changed by short steps on approaching the speeds corresponding to the maximum and minimum speeds of flow, and between each step the rotational speed is maintained constant and observation is made over a period of about one minute for points or short cross-stream streaks.

Fig. 7 (*a* and *b*) give photographs of the views seen in the free stream of the tunnel with the fluid-motion microscope (*a*) when the objective rotates at the speed corresponding to the mean speed of flow, and (*b*) when the objective rotates at the speed corresponding to the maximum speed of flow. The maximum speed of flow is only about 2 per cent. greater than the mean speed of flow, and for this reason the streaks in Fig. 7*b* are smaller than those usually seen.

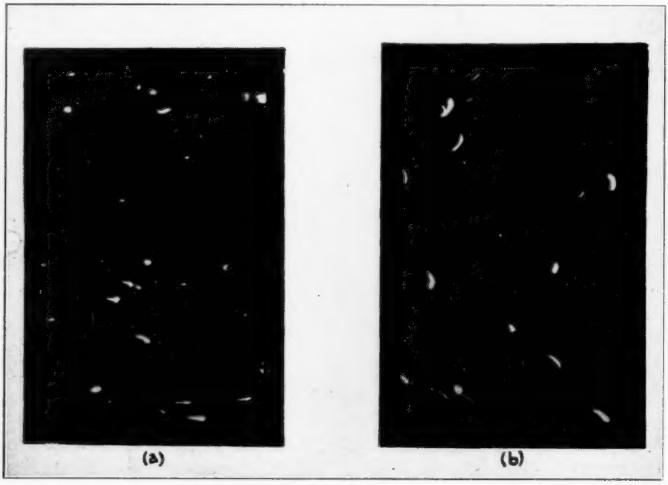


FIG. 7.

(8) As originally designed, the objective disc was coupled by a fine endless thread (fish line) to a flywheel driven by $\frac{1}{8}$ h.p. D.C. motor. The speed of the motor was regulated by a potentiometer resistance control on a 100-volt battery supply; and constancy of rotation was indicated by a stroboscope on the objective disc viewed in the light of a 50-cycle Neon lamp. This method of control can be made to give reliable results, but it suffers from the disadvantage that the speed of rotation changes as the motor warms up and it is occasionally difficult* to change the speed in the small steps needed for accurate measurement of turbulence. For these reasons an alternative variable speed drive of the friction disc type is now used. A photograph of this drive is given in Fig. 8. A variable speed is obtained by the radial traverse of a roller in rubbing contact with the plane surface of a rotating disc. The disc is rotated at a constant speed by a 1/20 h.p. synchronous motor (Klaxon) and the disc carrying the objective is connected by an endless belt pulley drive on the roller shaft. The roller is kept in contact with the driving disc by an adjustable spring device, and the radial position of the roller is given on a scale. The first tests on the smoothness of running of the drive showed the average speed of rotation was

* This difficulty only arises when the turbulence is small: e.g., 0.1 per cent. steps in speed are needed to measure a maximum turbulent velocity component which is 1 per cent. of the mean velocity to an accuracy of 10 per cent.

constant, but there was a small but periodic change of speed during a revolution. This variation of speed was attributed to a periodic change in the friction between the disc and its roller. The variation was reduced to a negligible amount after re-grinding the rubbing surfaces of the disc and roller, and re-aligning the axis of the roller.

(9) Provision is made to measure the maximum angular deviation of the path of a particle from the mean direction of flow. A slit ($\frac{3}{8}$ in. wide) in the image plane of the field lens allows particles to be viewed whilst they travel a known distance downstream, and the maximum distance across the stream they travel in the same time is determined from the maximum cross-stream length of the streaks seen whilst the objective rotates at or near the speed corresponding to the mean speed of flow. This cross-stream length is measured with a graticule in the eyepiece of the microscope. The maximum value of the tangent of the angular deviation of the particle path is given by the ratio of the maximum

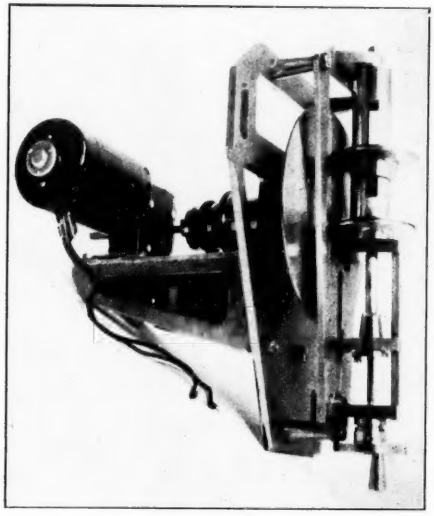


FIG. 8.
Variable-speed gear.

cross-stream length (corrected for the length of streak arising from the curvature of the path of the objective) to the length of the downstream path. The maximum value of the cross-stream component of turbulent velocity is determined from the maximum positive and negative angular deviations by the method given in an earlier paper.* Except near a surface, the maximum positive and negative angular deviations have the same numerical values, and the maximum value of the cross-stream component of turbulent velocity, denoted by v_T, is then given by

$$v_T = U\left[1 - \left(\frac{u_T}{U}\right)^2\right]^{\frac{1}{2}} \tan \Theta,$$

where U is the local mean velocity, u_T is the maximum value of the downstream component of turbulent velocity, and Θ is the maximum angular deviation. Notes on the fluid-motion microscope describing in further detail its method of working are given in an appendix.

* Fage (loc. cit.).

(ii) Fluid-Motion Microscope with Interrupter Disc.

(10) The speed of a particle can be determined from measurement of the length of its track, recorded for a known time of exposure, on a photographic plate. The plate is placed in the position normally occupied by the eyepiece of the fluid-motion microscope (Fig. 9), and particle images on the plate are obtained by the field lens and the objective lens (stationary) of the microscope. The time of exposure is fixed by an interrupter disc (shutter) rotating at a constant speed. The disc has 18 uniformly-spaced radial teeth, the angular width of each tooth being 8° and the angular width of the slot between two adjacent teeth 12°. The teeth of the interrupter disc behave as a stroboscope when viewed in the light of a Neon lamp (50 cycles per sec.), and by this means the rotational speed is kept constant. The interrupter disc with its slots covered acts as the objective disc in visual observation. To obtain sharp cut-offs, the radial edges of the teeth are chamfered, and the disc is mounted with the edges of the teeth in the focal plane of the field lens. The disc is rotated at a speed which allows two

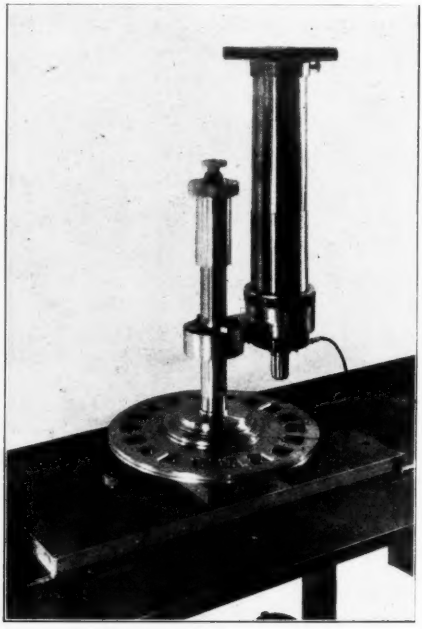


Fig. 9.
Microscope with interrupter.

or more complete streaks of a particle to be recorded on the photographic plate. Distances measured on a plate are from the beginning of one streak to the beginning of the next, and these measurements are not affected by particle size. The interrupter disc can be mounted so that as the sharp radial edges of the teeth cut the axis of the image beam they move either at right angles to or in the direction of motion of the particles. The former method is preferred (see Appendix).

(11) At least one-half of the light from the source of illumination is scattered and lost by reflection from the surfaces of the lenses in the illumination and optical systems and the tunnel window. This loss of light not only involves a

diminution in the brightness of the light falling on the plate from the particles; but that part of the scattered light itself which falls on the plate reduces the blackness of the background against which the streaks traced by the particles are photographed. It is essential therefore that the lenses and tunnel window should be clean and that whenever possible all extraneous light and reflections should be screened from the camera. Small particles of uniform size are essential, especially for photography of flow in a boundary layer, and the most suitable particles tried were those from aluminium powder sieved through a very fine wire gauze (mesh 1/240 in.), and having an average size of about 0.0015 in. (see §6). Particles are conveniently introduced into the water through a tube of fine bore mounted in front of the honeycomb of the tunnel and orientated so that they pass through the field of observation. A point on the plate is exposed to the light of a particle during the time the particle takes to cover its own length, and the quantity of light falling in the immediate neighbourhood of the point depends directly on the intensity of the source of illumination, the size of the particle, the square of the aperture of the

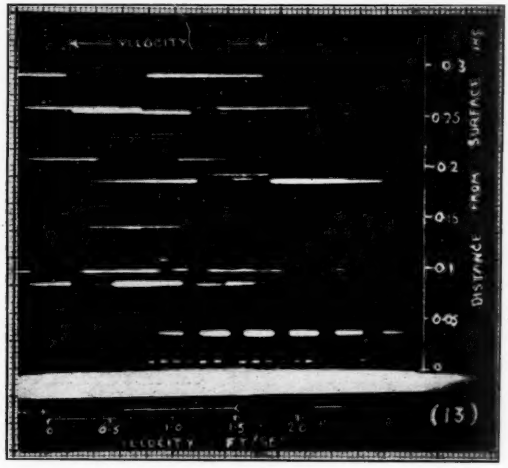


FIG. 10.

optical system, and inversely as the velocity of the particle and the square of the overall magnification. The appearance of the photographed tracks depends on the plate used. Three kinds of plate, Ilford Panchromatic H.P. 2, F.P. 1, and Process (backed and V.P. size) were tried. H.P. 2 plates give streaks of satisfactory density, but there is a background fog coupled with large grain size which tends to reduce the sharp contrast needed for accurate measurement of the length of a streak. F.P. 1 plates give good negatives, no background fog, and high-contrast images. Panchromatic Process plates have extremely fine grain, and give very high contrast and a hard dense image. In short, F.P. 1 and Process plates give more defined streaks than H.P. plates, but they record fewer streaks for they are only affected by the brightest particles.

Fig. 10 gives a photograph (enlarged) of particle tracks in the boundary layer of a long streamline body. The thickness of the boundary layer was about 0.25 in. The photograph was taken with a 2 ins. objective lens working at magnifications 2.6 : 1 with the field lens at 1 : 1. The plate was exposed for 1 sec., and immersed in standard developer for about $4\frac{1}{2}$ mins. The distance of a particle track from the surface can be measured to within $\pm$0.0002 in. (actual

distance), and the velocity calculated from the length of a track to within ± 1 per cent.

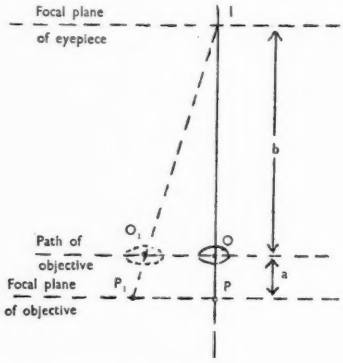
(12) Mr. C. A. Culverhouse assisted in the design of the water tunnel, and Mr. H. F. Lovesey in the construction of the tunnel and its apparatus.

Appendix.

Notes on Fluid-Motion Microscope.

The speed of a particle is determined from the rotational speed of the objective for which the image produced by the objective appears as a stationary point (or a short lateral streak). Assume for simplicity that the flow is rectilinear and that the objective can be treated as a thin lens.

Let U ft./sec. denote the velocity of the particle, $2\pi N$ rads./sec. the angular velocity of the objective, and r ft. the radial distance between the axis of rotation and the optical axis of the objective. The velocity of the particle in the focal plane of the objective is $m_1 U$, where m_1 is the magnification given by the field lens.



Let the particle image (produced by the field lens) be at the point P on the optical axis of the microscope. After a short time δt the particle image moves a distance $m_1 U \delta t$ to P_1, and the objective moves a distance $2\pi r N \,.\, \delta t$ to O_1. The image at the eyepiece remains at rest when $PP_1/OO_1 = PI/OI$, that is, when

$$U = \frac{2\pi r}{m_1}\left(\frac{a+b}{b}\right)N.$$

If m is the magnification given by the objective, and f its focal length, $1/a + 1/b = 1/f$, $m = b/a$, and

$$\frac{(a+b)}{b} = \frac{(1+m)}{m} = \frac{b}{(b-f)}.$$

Writing $U = KN$, where K is the calibration factor, we have

$$K = \frac{2\pi r\,(1+m)}{m m_1} = \frac{2\pi r b}{(b-f)\,m_1}.$$

The value of K is easily found by direct calibration. The microscope (with the field lens) is focussed on an evenly-divided linear scale, and the readings on the scale recorded against the angular displacements of the objective disc. The edge of the scale is set in the direction in which the velocity is to be measured, and the objective disc is mounted with its plane at right angles to the optical axis of the microscope, so that the movement of the objective is parallel to the edge of the scale when the optical axis of the objective is brought into coincidence with the common optical axis of the eyepiece and field lens. As the disc is given an angular displacement, the divisions of the scale apparently move

across the field of view, but they remain parallel to the eyepiece hair-line, initially set parallel to a division. If l is the linear displacement on the scale corresponding to an angular displacement θ of the disc, it follows from the relation $U = KN$ that $K = 2\pi l/\theta$. In the present apparatus $b \approx 10$ ins., $f \approx 2$ ins., $m \approx 1$, and for these values l/θ is constant over the entire range of θ within which the scale is seen (when $m_1 = 1$ the length of field seen is about 1 in.). The angle θ is determined from the linear displacement on a scale of a spot of light given by a long narrow beam of light reflected from a small mirror on the axis of the objective disc.

The motion imposed by the rotation of the objective disc can be resolved into an instantaneous linear velocity $2\pi rN$ at the axis of the objective and in a direction normal to the plane containing the optical axis and the axis of rotation, and an angular velocity $2\pi N$ of the objective about its axis. Since the objective lens is a spherical one, a rotation about its axis does not affect the view, so that calibration factor K obtained for particles on the optical axis of the system holds for all particles within the field of view. Strictly speaking, it is not possible to bring a particle moving in a linear path to apparent rest by movement of the objective in a circular path. With the present apparatus, the circular arc through which the objective moves whilst a particle is under observation is so small that the change in the imposed velocity in the mean direction of flow due to the curvature of the path of the objective is negligible (cosine error). The component of the imposed velocity at right angles to the mean direction is, however, not always negligible, and it is for this reason that a particle may appear as a stationary short streak when the objective rotates at the speed which brings the particle to apparent rest in the direction of flow.

Three objectives, screwed hard down on the plane surface of the rotating disc at 120° to each other and at the same radius (3 ins.) are used. These objectives are very closely matched, and particles of dust on a plane surface normal to the axis of the microscope remain sharply outlined as the optical axis of each objective is brought into coincidence with the optical axis of the eyepiece by angular displacement of the objective disc.

The calibration factor K depends on the magnification given by the field lens, and so on the distance between the field lens and the objective, here denoted by Z. The relation between K and Z is independent of the depth of the point in the water tunnel on which the microscope (with field lens) is focussed.

The calibration factor K is a linear function of Z over the range of m_1 (1 to 1.5) covered in the calibrations; and it was found convenient in practice to determine the value of K directly from this known linear relation and a measurement of Z.

The accuracy of speed measurement with the fluid-motion microscope depends on a judgment whether the image of a particle is a point (or a short lateral streak). If l is the length of the path of a particle through the light beam, M the total magnification and N the rotational speed of the objective which brings the particle to apparent rest, the downstream length of the streak seen when the objective rotates at a speed $(1 \pm a)N$ is aMl. If a streak of downstream length l_1 is taken to be a point, the percentage error in the measurement of the speed of the particle is $100\, l_1/Ml$. The error therefore varies inversely as the magnification and the length of the path of the particle through the light beam. The average diameter of the particles is 0.0015 in., the magnification given by the field lens is about 1 : 1, and the width of the slit in the focal plane of the field lens is 0.375 in. For these working conditions, the time a particle is in view is $0.375/12\,U$ sec., so that if a downstream streak whose length is double the diameter of the particle were mistaken for an image of the particle the velocity measured would be

$$U \pm \frac{0.0015}{12} \times \frac{12\,U}{0.375}, \text{ i.e., } U\,[1 \pm 0.004].$$

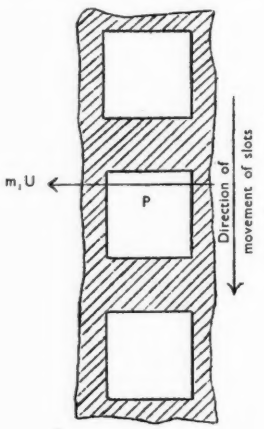
The error in velocity measurement would then be $\pm 0.004\,U$.

For a given light source, the brightness of an image decreases with an increase in the section of the light beam, with the magnification, and with the speed of the particle, but apparently increases with the darkness of the background against which the image is viewed. Light diffused by out-of-focus particles tends to brighten the background, and the darkest background is obtained when the depth of the field illuminated is the same as the depth within which particles are in sharp focus. This condition is suitable for laminar flow, but not for turbulent flow, for particles then move in paths inclined to the plane of the illuminating beam as well as in the plane, and if the beam is thin some of the particles will cross the beam so that their illuminated paths will be short and the accuracy of speed measurement will suffer. The depth of the light beam must therefore be sufficient to prevent such uncertainty arising. Speed measurement must also be based on observation of points (or streaks) given by particles which are in sharp focus. With a magnification of 40, the depth of focus is about 0.03 in., and a suitable depth of light beam is about 0.15 in.

Notes on Interrupter Disc.

(i) Teeth of Interrupter Disc Moving at Right Angles to the Mean Direction of Flow.

Let U be the speed of a particle,* P, moving in the mean direction of flow. Then $m_1 U$ is the speed of the image of the particle in the focal plane of the field lens, that is in the plane of the interrupter, where m_1 is the magnification given by the field lens. The time taken for a slot to cross the path of a particle



is $12/360N$ secs., where N is the rotational speed of the interrupter disc in revs./sec. The length of the exposed path in the image plane of the field lens is $12Um_1/360N$, and the length of the streak on the photographic plate is $12m_1m_2U/360N$, where m_2 is the magnification given by the objective lens. Similarly, the length of the gap between two consecutive streaks on the photographic plate is $8m_1m_2U/360N$. The distance on a photographic plate between the beginning of a streak and the beginning of the next streak, denoted by L, is therefore $(12+8)m_1m_2U/360N$, that is $m_1m_2U/18N$, and the velocity U is given by $18NL/m_1m_2$.

When the path of a particle is inclined to the mean direction of flow, the relative speed in the direction at right angles to the mean direction of flow

* The size of the particle is immaterial when measurements are made from the beginning of one streak to the beginning of the next streak.

between the particle image in the focal plane of the field lens and the teeth is $2\pi rN \pm m_1 V$, where r is the radius* from the axis of rotation to the particle image, V is the component of the velocity of the particle in the direction at right angles to the mean direction of flow, and the sign taken depends on the direction of V, being positive when the particle image moves in the opposite direction, and the particle itself in the same direction as the teeth. The time taken for a slot to cross the path of the particle is

$$\frac{2\pi r \times 12}{360\,(2\pi rN \pm m_1 V)}.$$

The length of the streak on the plate, taken in the mean direction of flow, is

$$\frac{2\pi r m_1 m_2 U \times 12}{360\,(2\pi rN \pm m_1 V)}.$$

Similarly, the length of a gap between two consecutive streaks on the plate is

$$\frac{2\pi r m_1 m_2 U \times 8}{360\,(2\pi rN \pm m_1 V)}.$$

The distance between the beginning of a streak and the beginning of the next streak, L, is therefore

$$\frac{2\pi r m_1 m_2 U}{18\,(2\pi rN \pm m_1 V)},$$

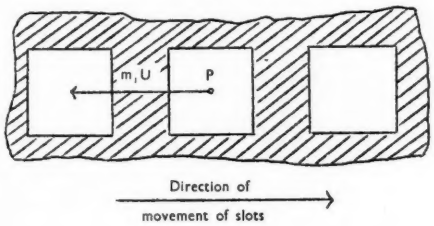
so that

$$U = \frac{18\,NL}{m_1 m_2}\left[1 \pm \frac{m_1 V}{2\pi rN}\right].$$

With the present apparatus $r = 0.25$ ft., $m_1 \approx 1$, and a convenient value of N for $U < 2$ ft./sec. is 5 revs. a second. For these working conditions the value of U is therefore given by the simple relation $U = 18\,NL/m_1 m_2$ to an accuracy within ± 1 per cent. provided $V < 0.08$ ft./sec., that is, provided $\alpha^\circ < 4.6/U$, where α is the inclination of the particle to the mean direction of flow.

(ii) Teeth of Interrupter Disc Moving in the Mean Direction of Flow.

Let U be the speed of a particle, P, in the mean direction of flow, and r the radial distance of the image of the particle given by the field lens from the axis of rotation of the interrupter disc. The teeth cutting the image beam move



in the direction of the particle and so in the opposite direction to the particle image. The speed of the teeth at radius r is $2\pi rN$, and, ignoring the small radial component of velocity arising from the circular path of the teeth, the speed of the teeth relative to the particle image is $(2\pi rN + m_1 U)$. The width of a slot at radius r is

$$\frac{2\pi r \times 12}{360}$$

* It should be noted that the radius r is not constant.

and the time the particle image takes to traverse a slot is

$$\frac{2\pi r \times 12}{360} \times \frac{1}{(2\pi rN + m_1 U)}.$$

The length of streak on the photographic plate is therefore

$$\frac{2\pi r \times 12}{360} \times \frac{m_1 m_2 U}{(2\pi rN + m_1 U)}.$$

Similarly, the length of a gap on the plate is

$$\frac{2\pi r \times 8}{360} \times \frac{m_1 m_2 U}{(2\pi rN + m_1 U)}.$$

The distance between the beginning of one streak and the beginning of the next streak, L, is therefore

$$\frac{\pi r}{9} \frac{m_1 m_2 U}{(2\pi rN + m_1 U)}.$$

It therefore follows that for given values of m_1, m_2, and N, the value of L depends on both r and U, and that for a given value of r the value of L is not directly proportional to U; also, the relation is only strictly true when the widths of the teeth and slots are negligibly small compared with r. For these reasons this method is not recommended, and the method in which the teeth move at right angles to the mean direction of flow is preferred.

THE PART OF SHEAR IN THE DEFORMATION OF I-BEAMS.

By Jean Drymael,

Assistant Professor in the University of Brussels.

Summary.

Under the influence of civil engineering construction the part played by shear in the deformation of beams is usually neglected. In aircraft construction, where weight is important, the approximation is sometimes rough. It is shown that, in I-beams, it is simple to take the deformation due to shear into account, and it appears due chiefly not to elementary deformations distributed along the length, but to discontinuities in the slope wherever there is a concentrated load, namely, at the supports.

1. Conventions.

It is assumed that the transverse dimensions of each flange are small compared with the height h of the beam, and that, in each cross section, the area of the web is small against the areas of the flanges.

The x axis is directed along the axis of the beam, and passes, in each section through the centre of gravity of the cross-section; the z axis is directed upwards and the y axis forms with them a left-hand system (Fig. 1).

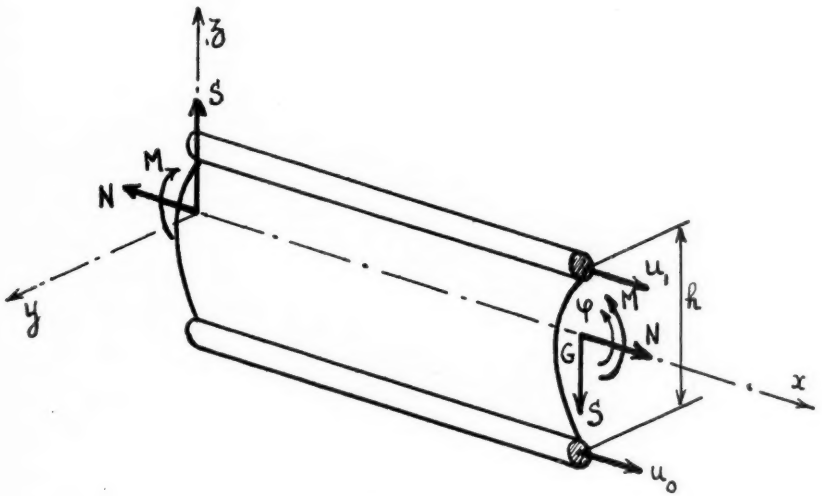


Fig. 1.

The axial force N on the beam is positive when there is tension; the shear S is positive when acting upwards on the part of the beam located on the positive side of the x axis, and the bending moment M is positive when the lower flange is in tension.

2. Stress of the Flanges.

Since the transverse dimensions of each flange are small, the normal stress may be considered as a constant; and, since the area of the web is small the part played by the latter in resisting bending moment is negligible.

Let N_0 and N_1 be the axial forces on the bottom and top flange, considered as positive when there is tension (Fig. 2). The balance of the beam requires that

$$N_0+N_1=N, \qquad N_0z_0+N_1z_1=-M \quad . \quad . \quad . \quad (1)$$

Let A_0 and A_1 be the areas of the flanges in a particular section, A and I the total area and the moment of inertia of the cross section about the centre of gravity.

$$A_0z_0+A_1z_1=0$$
$$A=A_0+A_1, \qquad I=A_0z_0^2+A_1z_1^2=A_1z_1h \quad . \quad . \quad . \quad (2)$$

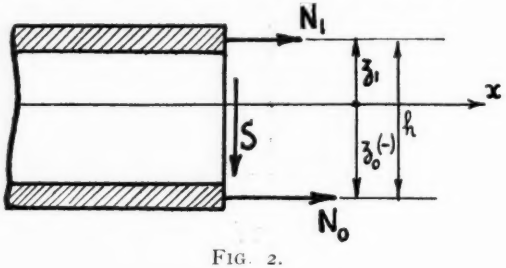


Fig. 2.

It is easily seen that the axial forces on the flanges equal

$$N_i=\frac{N}{A}A_i-\frac{M}{I}A_iz_i \qquad (i=0,\ 1) \quad . \quad . \quad . \quad . \quad (3)$$

3. Stress of the Web.

Since the axial stresses in the flanges are constant, there is no shear stress in them, and the whole shear is borne by the web. Now, since the static moment of the web is negligible against that of the flanges, the shearing force, that is the product of the shear stress τ by the thickness t, is constant throughout the height of the section. It has been shown in a previous paper* that

$$\tau t=\frac{S}{h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

even if the web is curved (Fig. 3).

It has been shown also that the total shear S must be applied eccentrically along a line called axis of the web, whose distance to the plane of the flanges is twice the mean distance y_m of the web.

4. Deformation of the Flanges.

Under the axial forces they bear, the flanges move in the x direction by the amount u_i $(i=0,\ 1)$. For each of them the extension (or contraction) equals

$$\frac{du_i}{dx}=\frac{N_i}{EA_i}=\frac{1}{E}\left[\frac{N}{A}-\frac{Mz_i}{I}\right] \quad . \quad . \quad . \quad . \quad (5)$$

The movement of each cross section in the plane of the beam may be considered as the sum of a translation of G and a rotation about this point. The longitudinal movement of G is

$$u_G=\frac{1}{h}(z_1u_0-z_0u_1) \quad . \quad . \quad . \quad . \quad . \quad (6)$$

* J.R.Ae.S., January, 1941.

and the angle of rotation, measured positively from x to z (Fig. 1) is

$$\phi = \frac{1}{h}(u_0 - u_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Thus

$$\frac{du_G}{dx} = \frac{N}{EA} \qquad \frac{d\phi}{dx} = \frac{M}{EI} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The first expression is the same as in the solid beams, and the second one is known as representing the curvature of the beam. It may still be considered as the " curvature " of the flanges, but no more as the curvature of the elastic axis (see further).

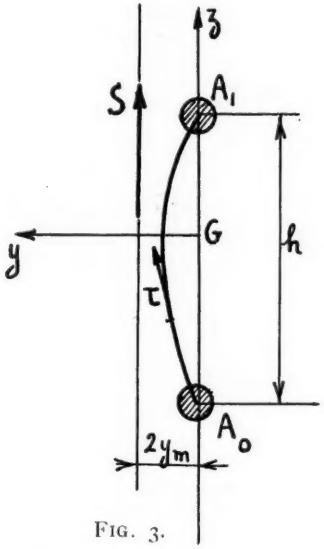


FIG. 3.

6. DEFORMATION OF THE WEB.

Provided a convenient set of stiffeners prevent the distortion of the cross section in its own plane, its movement may be considered as a translation and rotation in its plane. It has been shown* that the only component which is defined by the state of stress is the vertical movement w of the axis of the web. The horizontal translation and the angle of twist are indeterminate. The translation w is given by the differential equation

$$S = Ga\left[\phi - \frac{dw}{dx}\right]. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where a is the reduced area of the web, *i.e.*, if s is its length and if the thickness t is constant

$$a = st\left(\frac{h^2}{s^2}\right) = \frac{th^2}{s} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The reduced area equals the true area when the web is plane.

Hence the slope of a parallel to the x axis drawn in the " plane " of the web is

$$\frac{dw}{dx} = \phi - \frac{S}{Ga} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

*Loc. cit. The conventions of M and S have been reversed.

It appears thus that the slope of this " elastic axis " dw/dx is different from the slope ϕ of the cross section. If the web is as light as possible and if the modulus G is much smaller than E—which occurs particularly in wooden constructions—the difference may be very important.

If equation (11) is derived, the curvature of the elastic line is found to be

$$\frac{d^2w}{dx^2} = \frac{M}{EI} - \frac{p}{Ga} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

p being the distributed load applied on the beam. If l is the length of the beam, the bending moment is of the same order as pl^2, and, as a rule, the correction of curvature is negligible. But equation (12) does not apply wherever the shear is not derivable, *i.e.*, where there is a concentrated load. Equation (11) shows that, at these points there is a discontinuity in the slope of the beam which is proportional to the discontinuity of the shear, that is the concentrated load; and, though the correction of the curvature is almost negligible, those discontinuities in slope are able to produce movements of appreciable importance.

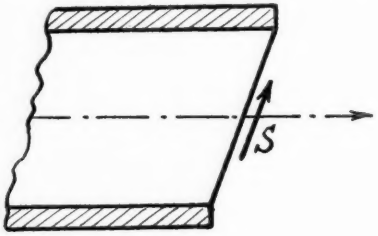


FIG. 4.

Among the discontinuities, that one must not be forgotten which appears at the built-in end of a beam; since, by definition, the angle ϕ is zero there, the initial slope of the beam equals $-S/Ga$.

Practically, the deformation due to shear is not, like that one due to bending moment, the sum of infinitely small deformations distributed along the whole length, but results chiefly from discontinuities in the slope curve, or angular points in the deflection curve. It is perhaps worth while to notice that, according to previous assumptions the cross section of the beam appears, after deformation, as shown by Fig. 4, with a crook between flange and web.

7. PRACTICAL METHOD TO DEAL WITH SHEAR DEFORMATION.

If the external supports of the beam are statically determinate, the procedure will be as follows (Fig. 5):—

a. Find the shear curve by integrating the distributed load curve, and taking into proper account the discontinuities due to concentrated loads.

b. Find the M curve by integrating the S curve and taking into proper account the discontinuities due to concentrated moments.

The constants of integration are determined either separately ($M=T=0$ at a free end) or together ($M=0$ at both simply supported ends) by the boundary conditions.

c. Draw the M/EI curve and integrate it, and find the slope curve by subtracting S/Ga from the integral.

d. Integrate the slope curve to find the deflection curve.

The constants of integrations for those two operations are again determined by the boundary conditions, either separately ($dw/dx=-S/Ga$, $w=0$ at a built-in end) or together ($w=0$ at each simply supported end).

If the supports are redundant, the supports of the non-built-in end, if there is any, or of either end if both ends are built-in will be removed; the slope and

deflection at the freed end will be determined as a function of the external loads and the unknown support reaction(s). The boundary conditions at that end determine their values at once.

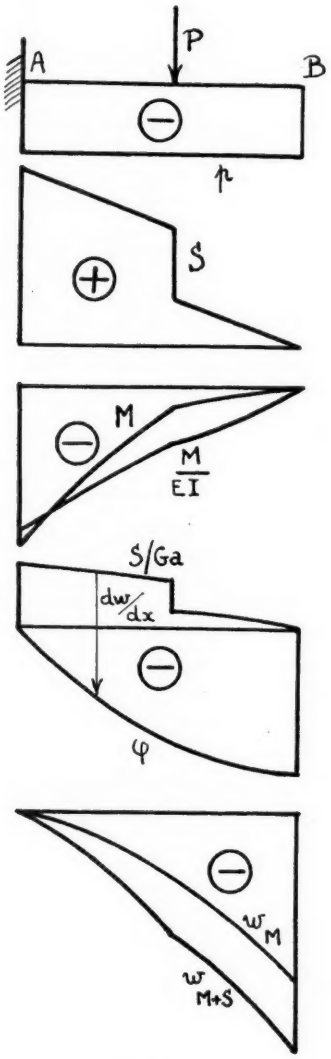


FIG. 5.

8. IMPORTANCE OF THE CORRECTION.

It is easy to determine the importance of the correction for a cantilever beam of equal resistance, bearing only a concentrated load at the free end (Fig. 6). If the flanges are symmetrical $z_1 = \pm h/2$. Let σ and τ be the stresses in the flanges and in the web, both constant.

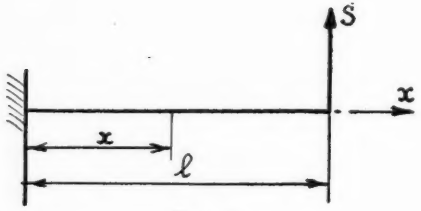


FIG. 6.

$$\frac{M}{EI}=\frac{2\sigma}{Eh} \qquad \int_0^x \frac{M}{EI}\,dx=\frac{2\sigma x}{Eh}$$

On the other hand

$$\frac{S}{Ga}=-\frac{\tau}{G}$$

Thus the slope is

$$\frac{dw}{dx}=\frac{2\sigma x}{Eh}+\frac{\tau}{G}$$

and the deflection

$$w=\frac{\sigma x^2}{Eh}+\frac{\tau x}{G}$$

At the free end

$$w_1=\frac{\sigma l^2}{Eh}\left[1+\frac{\tau}{\sigma}\frac{E}{G}\frac{l}{h}\right]$$

For a metallic material the ratio τ/σ of the admitted stresses equals roughly $G/E=0.4$. The correction has thus the importance of h/l, and 0.2 is not an unusual figure.

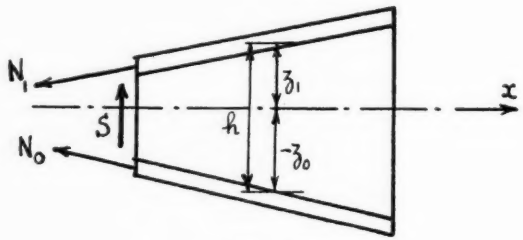


FIG. 7.

As a rule, however, the thickness of the web is larger than the required minimum, and the shear deformation is less important. But it must be borne in mind that the web, when very thin, is liable to buckle and, in that case, the shear deformation is greater than stated here.*

9. EFFECT OF TAPER.

Let a beam be considered whose height h is variable. It will still be supposed that each flange withstands only an axial force, and, as long as the taper is slight the projection of that force on the x axis may be considered as equal to the force itself. Thus the axial forces are determined in the same way as previously and equation (3) holds. The stress of the flanges is not affected by the taper.

* Cf. Wagner's theory. Z.F.M., 1929.

The axial forces in the flanges have components parallel to the z axis, respectively equal to

$$-N_1\frac{dz_1}{dx} \qquad -N_0\frac{dz_0}{dx}$$

Using equation (3) the sum of those forces is

$$-\left(N_0\frac{dz_0}{dx}+N_1\frac{dz_1}{dx}\right)=-\frac{N}{A}\left(A_0\frac{dz_0}{dx}+A_1\frac{dz_1}{dx}\right)+\frac{M}{I}\left(A_0z_0\frac{dz_0}{dx}+A_1z_1\frac{dz_1}{dx}\right)$$

Since equation (2) holds in every section

$$A_0\frac{dz_0}{dx}+A_1\frac{dz_1}{dx}=A_1z_1\left\{\frac{1}{z_1}\frac{dz_1}{dx}-\frac{1}{z_0}\frac{dz_0}{dx}\right\}=A_1z_1\frac{d}{dx}\log\left|\frac{z_1}{z_0}\right|$$

$$A_0z_0\frac{dz_0}{dx}+A_1z_1\frac{dz_1}{dx}=A_1z_1\left(\frac{dz_1}{dx}-\frac{dz_0}{dx}\right)=A_1z_1\frac{dh}{dx}$$

As a rule the ratio between z_0 and z_1 remains fairly constant along the length of the beam and the first sum may be ignored. The forces acting vertically upwards on the flanges equal thus

$$\frac{M}{I}A_1z_1\frac{dh}{dx}=\frac{M}{h}\frac{dh}{dx}$$

Since the total shear acting upwards on the beam is S, the part of it left for the web is

$$\Sigma=S-\frac{M}{h}\frac{dh}{dx}=M\frac{d}{dx}\log\left|\frac{M}{h}\right| \qquad . \qquad . \qquad . \qquad (13)$$

It follows that the shear Σ on the web is smaller than the total shear S when the absolute value of the bending moment grows in the same direction as the height h, which occurs normally.

Thus, usually, the taper lessens the stress of the web.

It will be supposed that, as previously, the shear is uniformly distributed over the height of the web, S being replaced by Σ in equation (4).

It must be noticed that the eccentricity of the shear Σ is less than the eccentricity of S, since the part of shear borne by the flange is obviously in their own plane, but this eccentricity varies now with the value of the bending moment (becomes greater than $2\,y_m$ if M grows in the wrong direction).

The exact study of the deformation is not so easy. Theoretically unequal extensions of the flanges involve a distortion of the web, and reciprocally, in such a way that the deformations due to normal stresses and to tangential stresses react on each other. But, since the shear deformation is only a fraction of the normal stress deformation it is useless to split hairs about it, and the method explained for beams of constant height will give a very good approximation, if S is replaced by Σ.

STRESS DISTRIBUTION IN METAL COVERED WINGS AND SIMILAR STRUCTURE.

By L. CROWTHER.

Recent investigations show that "shear lag" has a small effect on the distribution of the bending stresses in the section; but the effect of the stiffness variation, of the various parts of the structure, has a considerable bearing on this distribution.

Compression tests on panels of wing covering comprised 20 S.W.G. and 22 S.W.G. plating, with stringers of 18 S.W.G. to 22 S.W.G. rolled sections, show that, due to the bowing and waving of the light covering and stringers, the effective E is reduced to about 4.5×10^6 to 5×10^6 lbs. per sq. ins. for light alloy panels of these sizes. Compression tests on light alloy extruded struts show a value of E of 10×10^6 lbs. per sq. ins.

This means, that if the wing has two spars, with extruded or other stiff booms, and covering of light plate and stringers, the whole of the covering and the spars are fully effective on the tension side, but on the compression side, while the spar booms are fully effective, the covering and stringers are only effective in proportion to the ratio E_C/E_B, where

E_C = effective E of covering and stringers, and
E_B = effective E of the spar booms.

This is so, by virtue of the fact that the extensions of the covering and the spar booms must be equal, as they are fixed together, giving

$$\text{Stress in covering} = \text{stress in spar boom} \times E_C/E_B.$$

It means that when calculating the properties of the section in bending, the areas of the stringers and covering in compression, should be reduced in the ratio E_C/E_B; the stress obtained, using the resulting value of effective I, is of course the stress in the stiff spar booms; the stress in the covering and stringers is to be obtained by factoring down in the ratio E_C/E_B.

EXAMPLE.

A typical wing structure section is shown in Fig. 1. For simplicity of the arithmetic in the example, the covering is taken as being flat, and the nose and trailing edge covering is neglected.

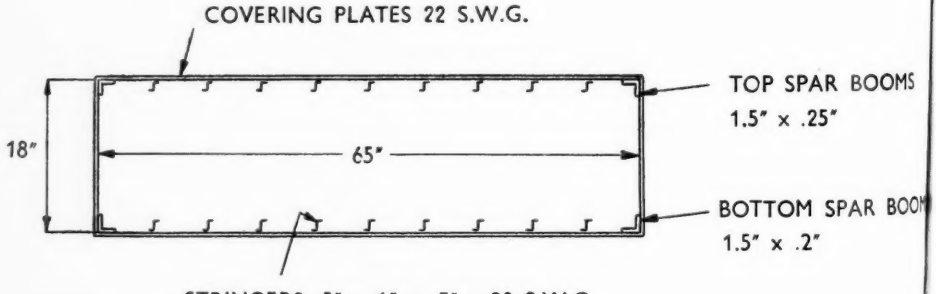


FIG. 1.

Diagram of section. Material—Light alloy.

EFFECTIVE PROPERTIES OF SECTION.

Item.	Effective Area ins.^{2}.	Distance from Section Centre Line $\bar{y}$ ins.	$Ae.\ \bar{y}$	Distance from N.A $=y$ ins.	Ay^2.
Top plating,					
$.05'' \times 0.028'' \times 4.5/10$ ...	0.82	+9.0	7.34	10.67	93.1
Top stringers,					
$10 \times 0.068 \times 4.5/10$ ...	0.306	+8.5	2.50	10.17	31.6
Top spar booms,					
2×0.685 ins.^{2}	1.37	+8.5	11.65	10.17	142.0
Bottom plating,					
$.05'' \times 0.028''$	1.82	−9.0	−16.4	7.33	97.7
Bottom stringers,					
10×0.068 ins.^{2}	0.68	−8.5	−5.78	6.83	31.6
Bottom spar booms,					
2×0.56 ins.^{2}	1.12	−8.5	−9.52	6.83	52.0
	6.116		−10.21		448.0

N.A. $= 10.21/6.116 = 1.67$ ins. below centre line of section.

The maximum B.M. on the section $= 1{,}100{,}000$ lbs. ins.

∴ The maximum bending stress on the tension side

$$= (1{,}100{,}000 \times 7.33)/(2{,}240 \times 448) = 8.06 \text{ tons/ins.}^2.$$

The maximum bending stress in the compression spar boom

$$= (1{,}100{,}000 \times 10.67)/(2{,}240 \times 448) = 11.7 \text{ tons/ins.}^2.$$

And the maximum bending stress in the compression side covering

$$= (1{,}100{,}000 \times 10.67)/(2{,}240 \times 448) \times (4.5/10) = 5.26 \text{ tons/ins.}^2.$$

PROOF OF METHOD.

Balance of boom loads.

Load in top plating $= 5.26 \times 1.82 = 9.56$ tons.

Load in top stringers $= 5.26 \times (10.17/10.67) \times 0.68 = 3.40$ tons.

Load in top spar booms $= 11.7 \times (10.17/10.67) \times 1.37 = 15.25$ tons.

Load in bottom plating $= -8.06 \times 1.82 = -14.68$ tons.

Load in bottom stringers $= -8.06 \times (6.83/7.33) \times 0.68 = -5.11$ tons.

Load in bottom spar booms $= -8.06 \times (6.83/7.33) \times 1.12 = -8.42$ tons.

$$9.56 + 3.40 + 15.25 = 28.21 = 14.68 + 5.11 + 8.42 \text{ tons.}$$

Total internal moment

$$= (9.56 \times 10.67) + (3.40 \times 10.17) + (15.25 \times 10.17) + (14.68 \times 7.33) + (5.11 \times 6.83) + (8.42 \times 6.83)$$

$$= 102 + 34.6 + 155 + 107.6 + 34.9 + 57.5 = 491.6 \text{ tons ins.}$$

$$= 1{,}100{,}000 \text{ lbs. ins.}$$

CONCLUSIONS.

Although it is realised that this method takes no account of the stiffening effect, on the edges of the covering, by the spars, it is considered that if a panel of the covering is tested in compression, to determine the effective E, and the failing stress, this method is more accurate than the ordinary engineer's method generally used, and also gives a more economical distribution of the bending stresses.

Appendix I.

Description of Typical Panel Tests.

Specimens were made up to represent panels of covering having zed stringers at 6 in. pitch and ribs at 12 in. and 18½ in. pitch.

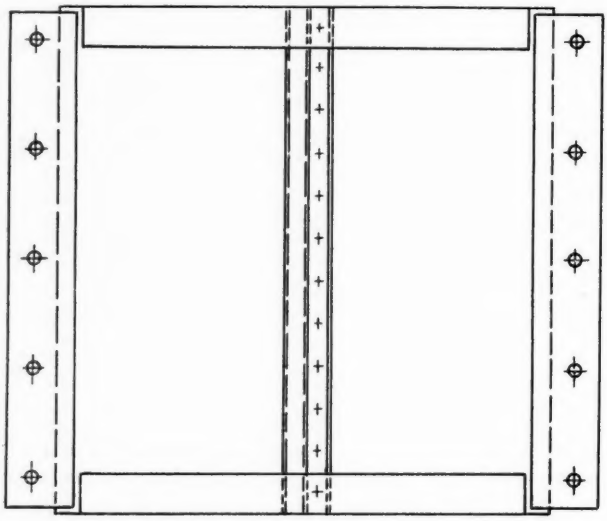


Fig. 2.
Diagram of test panel.

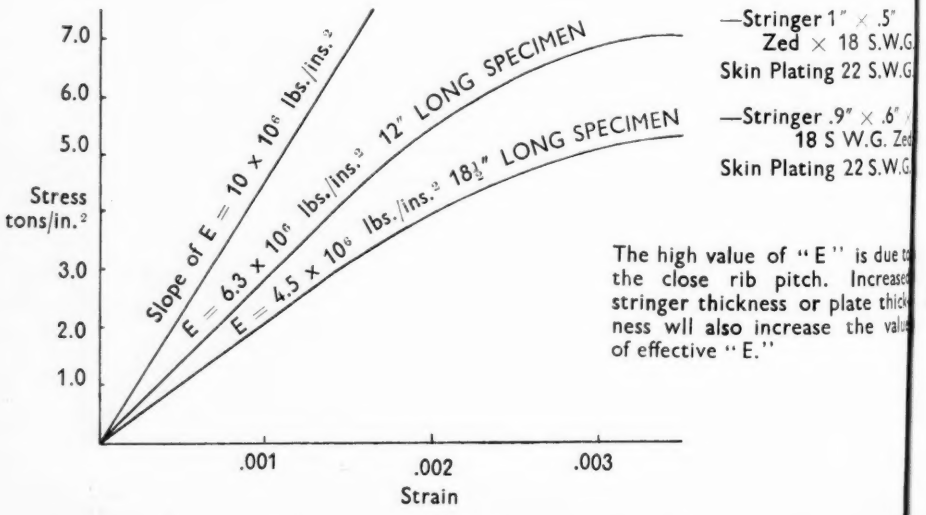


Fig. 3.
Stress-strain curves.

Plates 12 inches wide representing the skin covering had one stringer riveted on to the vertical centre line of the panel, and the two vertical edges of the panel were supported against buckling by wooden clamps, to simulate to the effect of the adjacent stringers. The top and bottom edges, *i.e.*, the loading surfaces of the specimen, had blocks of low temperature melting alloy one inch deep cast on, and machined off square, several $\frac{5}{16}$ in. diameter holes having previously been drilled through the "skin plating." These blocks represented the fixing at the ribs.

A correction for the effect of the "edges" was made; this was estimated after tests were carried out on panels having no stiffening except the wooden "edge clamps." It was found, however, that the correction to the mean failing stress, for the effect of the edges, was small.

The diagrams show the panel and the stress strain curves for two test panels. The stress plotted being the mean for the skin and the stringer. It will be noted that with the close rib spacing (12 in.), the effective E is appreciably higher than with the $18\frac{1}{2}$ in. rib spacing.

The tests were conducted by Messrs. Saunders-Roe in their Mechanical Test Laboratory, from whom permission has been obtained to publish these results.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

SEVENTY-SIXTH ANNUAL REPORT OF THE COUNCIL, 1940-1941.

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Professor L. Bairstow (Chairman), Mr. S. Camm, Captain P. D. Acland, Mr. Griffith Brewer and Mr. H. E. Wimperis.

REPRESENTATIVES ON OTHER BODIES.

The following were appointed as the Society's Representatives on other bodies :—

Advisory Committee for Aeronautical Engineering of the City and Guilds of London Institute: Professor F. T. Hill and Captain J. Laurence Pritchard.

Advisory Council of the Science Museum: Lord Sempill.

Air League of the British Empire: Mr. W. O. Manning and Mr. Griffith Brewer.

Association of Special Libraries and Information Bureaux: Mr. J. E. Hodgson (Honorary Librarian).

British Gliding Association: Council: Mr. W. O. Manning.

Technical Committee: Captain J. Laurence Pritchard, Professor F. T. Hill.

British Standards Institution, Aircraft Committee: Major R. H. Mayo and Dr. H. C. Watts.

British Standards Institution, Committee on Symbols and Abbreviations Used in Engineering: Dr. H. Roxbee Cox.

British Standards Institution Technical Committee on Aircraft Nomenclature: Professor L. Bairstow, Captain J. Laurence Pritchard.

British Standards Institution, Units and Technical Data Committee: Lieut.-Col. W. Lockwood Marsh.

Engineering Joint Council: Mr. C. R. Fairey.

Engineering Joint Council, Special Educational Representative: Professor G. T. R. Hill.

The Guild of Air Pilots and Air Navigators of the British Empire, Sefton Brancker Memorial Fund Committee: Captain P. D. Acland.

Joint Standing Committee with the Society of British Aircraft Constructors and the Royal Aero Club: Mr. E. F. Relf, Lord Sempill, Lieut.-Col. J. T. C. Moore-Brabazon, Air Vice-Marshal R. M. Hill, Mr. W. C. Devereux.

National Central Library: Mr. J. E. Hodgson (Honorary Librarian).

Professional Classes Aid Council: Lord Sempill.

Seagrave Memorial Fund Committee: Mr. C. R. Fairey.

Ministry of Labour, Engineering Advisory Committee: Mr. A. H. R. Fedden, Captain J. Laurence Pritchard.

Institution of Mechanical Engineers, Committee on Splined and Serrated Shafts: Mr. L. Mawer.

Institution of Mechanical Engineers, National Certificates and Diplomas in Mechanical Engineering: Mr. A. H. R. Fedden and Professor F. T. Hill.

Institute of Petroleum—Summer Meeting on Fuels for Internal Combustion Engines: Mr. D. R. Pye.

Society of Automotive Engineers—Conference May 2nd-June 8th, 1939: Mr. F. Handley Page, Mr. E. Hives, Mr. W. C. Devereux, Major R. H. Mayo.

Institution of Civil Engineers—Conference on Engineering Education and Training: Professor F. T. Hill.

British Standards Institution—Conference on the Standardisation of Letter Symbols in Science and Technology: Professor L. Bairstow.

British Standards Institution—Conference on Standardisation of Jewels and Pivots for Instruments: Major B. W. Shilson.

MEMBERSHIP.

The Membership of the Society for 1940, the first full year of war, shows a net increase, after allowing for members suspended, of 75, over 1939. The figures in brackets give the membership for 1939. This year, under the new rules passed in January, 1940, the Membership and Associate Membership grades

were abolished and amalgamated with the Fellowship and Associate Fellowship grades.

With the rapid expansion of the Aircraft Industry and the Royal Air Force there has been a considerable increase in applications for membership of the Society. Most of these applications have been rejected as not complying with the rules and the Council have no intention of relaxing the rules owing to the temporary situation created by the war conditions.

It is satisfactory, however, to note that there is a very considerable increase in recent months in the number of applications to take the examinations of the Society.

MEMBERSHIP OF THE SOCIETY, DECEMBER, 1940.

	Current Members.		Honorary and Life Members.		Suspended Members.		Totals.	
Fellows	216	(178 Fellows) (48 Members)	21	(22 Fellows) (1 Member)	7	(2 Fellows) (1 Member)	244	(202 Fellows) (50 Members)
Associate Fellows	973	(734 A.F.'s) (178 A.M.'s)	5	(5)	45	(28 A.F.'s) (9 A.M.'s)	1023	(767 A.F.'s) (187 A.M.'s)
Associates	323	(273)	3	(3)	32	(22)	358	(298)
Graduates	137	(102)	—	—	5	(3)	142	(105)
Companions ...	117	(109)	10	(10)	11	(7)	138	(126)
Founder Members	17	(18)	1	(1)	1	(1)	19	(20)
Students	556	(614)	—	—	74	(58)	630	(672)
Temporary Honorary Members ...	—	—	33	(41)	—	—	33	(41)
Totals ...	2339	(2254)	73	(83)	175	(131)	2587	(2468)

NOTE. Figures in brackets give the membership as at December, 1939.

DONATIONS.

The Council have to thank the Air Ministry for the sixteenth year in succession for their grant of £250 to the Funds of the Society, and the Society of British Aircraft Constructors for a similar grant over the same period.

In the last Council Report a history was given of the initiation and progress of the Endowment Fund. The table below gives the progress of the Endowment Fund up to date:—

	£	s.	d.
December, 1926	575	0	0
December, 1927	597	2	0
December, 1928	1,047	18	0
December, 1929	1,077	6	0
December, 1930	1,265	10	0
December, 1931	1,935	10	0
December, 1932	2,196	2	0
December, 1933	9,716	19	5
December, 1934	10,131	14	11
December, 1935	10,895	10	7
December, 1936	11,138	16	7
December, 1937	11,474	3	7
December, 1938	12,211	12	11
December, 1939	51,048	14	6
December, 1940	64,740	17	9

SOCIETY'S HEADQUARTERS.

The Society has continued to function from its Headquarters, No. 4, Hamilton Place, since the outbreak of war. In September, 1939, temporary offices were made available in the country, and have remained available since. Except for the first fortnight in September, when these arrangements were being made, however, the whole of the staff has continued to work in London.

In the autumn of 1940 bombs dropped on two occasions close to the building and considerable damage was done, by the blowing in of windows and window frames. These have been temporarily boarded up until the end of the war and other precautions taken to safeguard the building as far as possible against further damage. All the staff in turn are on duty for fire watching, and, in addition, two of them are regular Air Raid Wardens.

LIBRARY.

Mr. J. E. Hodgson, Hon. F.R.Ae.S., completed his seventeenth year as Honorary Librarian, and the Council wish to place on record their appreciation of the valuable advice he has given on all matters pertaining to the Library.

At the outbreak of war the more valuable and irreplaceable books in the Library were stored in the country. During the last year a complete catalogue of the Library, including pamphlets, has been prepared in author and title index form, and this catalogue is now in course of publication.

During the year many slides, photographs and books have been presented to the Library, and the Council wish particularly to record their appreciation of these gifts.

ANNUAL GENERAL MEETING, MARCH 30TH, 1940.

The following is an abbreviated Report of the Annual General Meeting of the Society, held on Saturday, March 30th, 1940, at 3 p.m.

Present:—In the chair: Mr. Griffith Brewer (Vice-President).

J. E. Allen (Companion).
The Hon. Alan R. Boyle (A.F.).
Wing Cmdr. T. R. Cave-Browne-Cave (F.).
Miss L. Chitty (F.).
Dr. H. Roxbee Cox (F.).
W. C. Devereux (F.).
J. E. Chorlton (Companion).
E. C. Gordon England (F.).
C. G. Grey (Founder Member).
R. Hollingworth (A.F.).
Major D. H. Kennedy (F.), Honorary Treasurer.
P. G. Masefield (A.F.).
H. Myers (F.).
C. W. Pidcock (A.F.).
D. Stevenson (A.F.).
A. Hessell Tiltman (F.).
M. H. Volk (F.).

In attendance: The Secretary.

1. The Secretary read the Notice convening the Meeting.

2. The Chairman said he must first of all convey the regrets of the President, who was not able to take the chair on account of illness. He was sure they would all wish him a rapid recovery.

Last year, the President not only had the great pleasure in announcing that they had acquired a new home of their own, but he outlined many of the activities which the Council had in mind and projects which they intended to carry out during the next twelve months or so. The increasing anxiety of events in Europe and the final outbreak of war on September 3rd affected the Society as they had affected every organisation and individual in this country. Nevertheless, he was glad to be able to say the Society was in a much more powerful position than it was last year. He could look forward with certainty to the growing prestige of the Society to its taking part more actively than ever in aeronautical engineering, science and education.

In March of last year the Society formally took over No. 4, Hamilton Place, and on two days in June held a Reception so that as many members as possible could have the opportunity of seeing their magnificent new home under the best possible conditions.

Plans for holding an International Congress in July, 1940, at Stratford-on-Avon were well advanced at the beginning of last September and many international figures had promised to attend the Congress and lecture with all the authority of their experience on subjects of vital importance to aeronautical engineering all over the world. This Congress, would indeed, have been one of the most important aeronautical congresses of recent years, for it not only was sponsored by the Society, but it had the direct official backing of the Air Ministry and the Society of British Aircraft Constructors and the active help of various aeronautical bodies. It had been a great disappointment to the President and Council that this Congress had, owing to the European situation, been postponed.

It will be seen from the Report of the Council that the Society has been pressing forward with that vitally important subject, the education of the aeronautical engineer. Early in the year the University of London agreed to the creation of an aeronautical engineering degree, so putting aeronautical engineering on the same footing as that of other forms of engineering, as Civil and Electrical. At the same time, the Council approached the Society of British Aircraft Constructors, and a Committee was formed to draft out a suggested training and syllabus for training aircraft apprentices which would be on national grounds. This report is now under discussion with the Engineering and Allied Employers' National Federation, and he had every confidence that shortly there would be a scheme in existence so that every boy in the country who entered aviation would have the opportunity to rise to the highest posts in the industry by means of a technical and practical ladder which had been built for him by the Society of British Aircraft Constructors and the Society.

He did not propose to refer to the Council Report in great detail as they had it before them, but he would like to touch briefly on one or two points. The membership had again shown satisfactory increase and for the first time in the history of the Society is approaching the 2,500 mark.

In the Council Report a table is given of the growth of the Endowment Fund. In December, 1938, the fund stood at about £12,000. At the end of last year there is shown what he considered to be the most satisfactory increase to £51,000. Most of these donations are given over a seven year period, so that the full effect of them does not show immediately. At the end of that time, however, the Endowment Fund should have reached a sum of at least £125,000.

In the Report you will find the audited accounts of the Society. The income and expenditure account shows an excess of expenditure over income for the year of a little over £1,000. This is wholly due to the added expenses of moving into No. 4, Hamilton Place, the preliminary cost of the 1940 Congress, and other non-recurring items. On general grounds, it appears that the finances of the Society are on an eminently satisfactory basis and hold out every prospect in the future of enabling them when the time comes to go forward with a vigour and enterprise which has not been possible before.

He was glad to be able to say that the Journal, which is one of the most important assets of the Society, has for the first time in its history shown an increase of income over expenditure. During the year the sales revenue increased by over 50 per cent., a very remarkable tribute to its value.

On the outbreak of war the Council came to the decision that the very excellent programme of lectures which had been arranged for, should be postponed until at least early in 1940, when the Council could review the general situation and consider the possibility of resuming the lecture programme. Unfortunately, all lectures must be submitted to the Censorship, and the first one due to be delivered on March 12th had to be postponed indefinitely on account of censorship action. How far it will be possible to go ahead, he was not yet in a position to say.

Finally, he would like to pay a tribute to those Officers of the Society and Committees who have worked so willingly and fully on behalf of the Society. Although at times there have been different opinions about the way to do things, he had felt throughout that everyone in the Society with whom he had come into contact had only one thing at heart, and that was the welfare of the Society.

The Chairman then called upon the meeting for any comments on the Annual Council Report, or to put forward any constructive suggestions they wished.

3. In reply to questions by Wing Commander T. R. Cave-Browne-Cave with reference to the proposed Degree in Aeronautics, the Chairman asked the Secretary to explain the position. The Secretary drew attention to the fact that an announcement had been made in the Journal in January about the proposed degree, and that the Society now awaited the Syllabus from the Board of Studies of the University of London. With regard to National Certificates in Aeronautical Engineering, raised by Wing Cmdr. Cave, the Secretary explained that the Society already appoints the Assessor, and if it was thought fit to press for such Certificates, the Assessor would be able to advise the Society.

4. The Secretary read the names of ten members nominated to fill the ten vacancies on the Council. As only ten members had stood for Council no ballot had been necessary.

Professor L. Bairstow.	Mr. W. C. Devereux.
Mr. R. Blackburn.	Mr. E. C. Gordon England.
Mr. Griffith Brewer.	Captain A. G. Lamplugh.
Mr. S. Camm.	Mr. D. R. Pye.
Dr. H. Roxbee Cox.	Mr. Hessell Tiltman.

5. Mr. W. C. Devereux, Chairman of the Finance Committee, proposed, and Wing Commander T. R. Cave-Browne-Cave seconded, that Messrs. Price, Waterhouse and Company be re-appointed Auditors to the Society. The proposal was carried unanimously.

6. Mr. C. W. Pidcock, Associate Fellow, suggested the Society should set up an Advisory Committee for inventions. After some discussion it was agreed that the suggestion should be brought to the notice of the Council.

Special General Meetings.

Special General Meetings were held on January 27th, 1940, and February 10th, 1940, to pass new Rules, following proposals put forward at the Annual General Meeting in March, 1939. A report of these meetings appeared in the Journal for March, 1940, on page 223.

President.

Mr. Griffith Brewer, Hon. F.R.Ae.S., was elected President of the Society for the year October, 1940-September, 1941.

Vice-Presidents.

Lieut.-Colonel the Rt. Hon. J. T. C. Moore-Brabazon, M.C., F.R.Ae.S., M.P., and Professor L. Bairstow, C.B.E., F.R.S., F.R.Ae.S., were elected Vice-Presidents for the year 1940-1941.

Medals and Awards.

The Council decided to make no awards for the year, with the exception of the Elliott Memorial Prize and the Major Baden-Powell Memorial Prize. The former is awarded twice yearly (awarded three times this year by special arrangement) to the Apprentice at Halton who has the highest percentage of marks in the passing out Examination; and the latter to the Student who is considered best by the Examiners in the Associate Fellowship Examination.

The Elliott Memorial Prize was awarded to:—Aircraft Apprentice R. Burrows, Leading Aircraft Apprentice C. J. Pearson and Corporal Apprentice L. Card.

The Major Baden-Powell Memorial Prize was awarded to:—Mr. H. D. Conway, Mr. D. I. Vickery.

HONOURS.

The following members were recipients of Honours during the year:—

Knight Bachelor.—F. S. Spriggs, Esq. (Honorary Fellow).

C.B.—R. A. Watson Watt, Esq. (Fellow), Acting Air Marshal A. G. R. Garrod, O.B.E., M.C. (Associate), Acting Air Vice-Marshal R. G. Parry, D.S.O. (Associate Fellow).

M.C.—Acting Squadron Leader W. W. Straight, A.A.F. (Companion).

C.B.E. (Military Division).—Group Captain A. de T. Nevill, R.N.Z.A.F. (Associate Fellow), Group Captain W. H. Primrose, D.F.C. (Associate).

C.B.E. (Civil).—S. Camm, Esq. (Fellow), A. G. Elliott, Esq. (Fellow), N. Rowbotham, Esq. (Associate Fellow).

O.B.E. (Military Division).—Wing Commander (Temp. Group Captain) E. C. Wackett, R.A.A.F. (Associate Fellow), Major E. M. Sinauer (Temp. Lieut.-Col.), M.C. (Associate Fellow).

O.B.E. (Civil).—Captain J. G. Hopcraft, M.C. (Associate Fellow), R. K. Pierson, Esq., M.B.E. (Fellow), Captain J. Kelly Rogers, R.A.F.O. (Associate Fellow).

SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS' SCHOLARSHIPS.

The Scholarships Selection Committee of the Society of British Aircraft Constructors and the Royal Aeronautical Society made awards of S.B.A.C. Scholarships to the following:—

C. A. Chapman.	H. J. S. Pinsent.
J. C. Goodwin.	G. D. Poole.
P. L. B. Graham.	P. W. Wreford-Bush.

The Awards, now in their sixth year, have had most satisfactory results. The regular reports from firms of the progress of those awarded Scholarships show that the scheme has been thoroughly worth while.

It may be recalled that these Scholarships are tenable for a period of four years. Holders of Scholarships are given a thorough workshop and theoretical training and undertake to sit for the Associate Fellowship Examinations of the Society, or an exempting examination.

WILBUR WRIGHT MEMORIAL LECTURE.

The 28th Wilbur Wright Memorial Lecture was delivered on May 30th, 1940, by Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S., A.F.I.Ae.S., Chief Technical Officer, Air Registration Board, on "Looking Forward. Prolegomena for a Detailed Study of the Future of British Civil Aviation." A full report was published in the Journal of the Society for September, 1940.

LECTURE PROGRAMME.

For a number of causes it was not found possible to arrange a full programme of lectures in London. The following lectures were read during the year:—

April 12th, 1940.—"The History and Progress of Refuelling in Flight." Sir Alan Cobham, K.B.E., A.F.C., Hon. F.R.Ae.S., and Mr. Marcus Langley, F.R.Ae.S.

April 19th, 1940.—"Some Aspects of the Aerial Warfare in the German-Polish Campaign," J. J. Dziewonski and S. Rogalski.

BRANCHES.

Australian.

Hon. Sec.: J. B. Mills, B.Sc., Science House, Gloucester and Essex Streets, Sydney, Australia.

Belfast.

Hon. Sec.: W. H. Hambrook, A.F.R.Ae.S., Short and Harland, Limited, Queen's Island, Belfast.

Bristol.

Hon. Sec.: S. G. Nash, A.F.R.Ae.S., Whyteleafe, 4, Kenmore Grove, Filton Park, Bristol, 7.

Brough.

Hon. Sec.: S. J. Smyth, A.F.R.Ae.S., Blackburn Aircraft, Limited, Brough, East Yorks.

Cambridge University Engineering and Aeronautical Society (affiliated to the Royal Aeronautical Society).

Sec.: J. G. Lubbock, Trinity College.

Coventry.

Hon. Sec.: J. A. Beardsall, c/o Armstrong Whitworth Aircraft, Ltd., Whitley, Coventry.

Gloucester and Cheltenham.

Hon. Sec.: F. B. Ford, A.F.R.Ae.S., St. Margaret, Brockworth, Nr. Gloucester.

Hatfield.

Hon. Sec.: H. W. L. Calder, A.R.Ae.S., de Havilland Aircraft Company, Limited, Hatfield, Hertfordshire.

Isle of Wight.

Hon. Sec.: M. J. Brennan, A.F.R.Ae.S., c/o Technical Office, Saunders-Roe, Ltd., Cowes.

Manchester.

Hon. Sec.: J. E. A. Waterfall, 56, Manor Avenue, Ashton-on-Mersey, Cheshire.

Medway.

Hon. Sec.: J. W. Loader, B.Sc., A.F.R.Ae.S., 174, City Way, Rochester.

Montreal Aeronautical Section.

Address: Engineering Institute of Canada, 2050, Mansfield Street, Montreal, Canada.

Ottawa Aeronautical Section.

Hon. Sec.: M. S. Kuhring, A.R.Ae.S., National Research Council, Aeronautical Laboratory, Ottawa, Canada.

Portsmouth.

Hon. Sec.: J. F. Foss, Airspeed (1934) Limited, the Airport, Portsmouth, Hants.

Southampton.

Hon. Sec.: T. Tanner, A.C.G.I., D.I.C., A.F.R.Ae.S., 1, The Retreat, Southsea, Hants.

Weybridge.

Hon. Sec.: D. L. Ellis, A.F.R.Ae.S., Vickers Limited, Weybridge, Surrey.

Yeovil.

Hon. Sec.: L. A. Lansdown, Esq., Westland Aircraft Works, Yeovil, Somerset.

BRANCH SCHOLARSHIP.

The Coventry Branch have founded a Scholarship with the object of encouraging members of the Branch to become full members of the Society, and to provide funds for successful candidates to complete their education to the required standard. The first award was made to Mr. R. D. Lowe, a member of the Coventry Branch.

STANLEY SPOONER SCHOLARSHIP FOR AERONAUTICAL RESEARCH.

Under the will of the late Mr. Stanley Spooner, the Founder of "Flight," who died during the year, a sum of £5,000 was left to the Society for the founding of a Stanley Spooner Scholarship for Aeronautical Research. The legacy does not become payable until the death of two life tenants of the amount.

GRADUATES' AND STUDENTS' SECTION.

It has not been found possible to arrange the usual lectures and visits for the Graduates' and Students' Section.

Officers for 1940.

Chairman: Mr. P. G. Masefield, M.A., A.F.R.Ae.S.

Vice-Chairman: Mr. R. B. Wilkinson.

Honorary Secretary: Mr. W. Tye, B.Sc., A.F.R.Ae.S.

ASSOCIATE FELLOWSHIP AND ASSOCIATE MEMBERSHIP EXAMINATIONS.

The results of these examinations were published in the Journal for March, 1940, and July, 1940.

MEMBERS ELECTED DURING 1940.

The names of members elected in the various grades of the Society during 1940 have been published regularly in the Monthly Notices at the beginning of each issue of the Journal.

ACKNOWLEDGMENTS.

The Council acknowledge with grateful thanks the gifts of books, photographs, Journals and historical papers from members during the year. All these gifts have been acknowledged in the Monthly Notices of the Journal as received.

FINANCE.

The Income and Expenditure Accounts and Balance Sheets of Aerial Science, Limited, and Aeronautical Trusts, Limited, for 1940 are published in this issue of the Journal.

The Income and Expenditure Account of Aerial Science, Limited, shows an excess of income over expenditure for the year of £1,169 1s. 3d., as against an excess of expenditure over income for 1939 of £1,113 4s. 0d.

JOURNAL.

The Journal of the Society has maintained its high standard in face of the difficulties caused by the shortage of paper and the lack of lectures and the

(*continued on page* 168)

THE ROYAL

(Aerial

Balance Sheet,

	£ s. d.	£ s. d.	
Share Capital—			
Authorised—			
20 Shares of 1/- each	1 0 0		
999 Shares of £1 each	999 0 0		
	1000 0 0		
Issued—19 Shares of 1/- each, fully paid		19 0	
Bank Overdraft		624 9 10	
Sundry Creditors		893 7 10	
Subscriptions and Other Amounts Received in Advance		265 18 8	
Staff Pensions Fund		407 7 1	
Income and Expenditure Account—			
Balance at 31st December, 1939	1759 15 3		
Add—Surplus of Income over Expenditure for year to date	1169 1 3	2928 16 6	
		£5120 18 11	

We report to the Members that we have examined the above Balance Sheet with the Books and are of the opinion that the Balance Sheet is properly drawn up so as to exhibit a true and correct information and the explanations given to us and as shown by the Books of the Society.

3, Frederick's Place, Old Jewry, London, E.C.2.
4th March, 1941.

Income and Expenditure Account

	£ s. d.	£ s. d.	£
			1939
To Establishment Expenses—			
Ground Rent, Heating, Lighting and Insurance		1380 12 5	(1285
,, Office and Staff Expenses—			
Salaries	2089 5 9		(2391
Printing and Stationery	406 6 10		(832
Postages and Telephone	315 16 5		(416
Other Charges	966 4 11	3777 13 11	(1061
			(4702
,, Meetings		23 1 6	(128
,, Library Expenses		90 11 9	(40
,, Prizes and Donations		5 5 0	(32
,, Legal and Professional Charges		80 1 6	(273
,, Staff Pensions Fund		100 0 0	(100
,, Balance, being Surplus of Income over Expenditure for year carried to Balance Sheet		1169 1 3	
		£6626 7 4	

W. C. DEVEREUX, Chairman, Finance Committee.
A. N. D. SMITH, Honorary Accountant.

AERONAUTICAL SOCIETY

Science Limited)

31st December, 1940.

	£ s. d.	£ s. d.
Printed Books, Bindings, Old Prints, etc., at cost, less amounts written off		50 0 0
Stock of JOURNALS *and other Publications*		1 0 0
Investment in and amount due from Subsidiary Company Aeronautical Trusts Limited—		
21 Shares of 1/- each, fully paid, at cost	1 1 0	
Amount due on Current Account	2089 19 3	2091 0 3
Staff Pensions Fund—		
Investment, at cost—		
£441 18s. 0d. 2½ % Funding Loan, 1956/61...	401 4 2	
Cash at Bank	6 2 11	407 7 1
Sundry Debtors	... ...	1847 1 4
Cash at Bank and in Hand	... ...	724 10 3
		£5120 18 11

of the Society, and have obtained all the information and explanations we have required. We view of the state of the Society's affairs as at 31st December, 1940, according to the best of our

(Signed) PRICE, WATERHOUSE & CO.

for the Year ending 31st December, 1940.

	£ s. d.	£ s. d.	£ s. d. 1939 Figures
By Annual Subscriptions	... ...	5428 3 10	(5084 1 0)
,, Donations	... ...	500 0 0	(500 0 0)
,, Examinations—			
Fees Received	141 12 0		(192 16 6)
Less Expenses	140 16 5	15 7	(174 1 0)
			(18 15 6)
,, Receipts from JOURNAL and Sundry Publications—			
Sales	1615 18 11		(2053 16 9)
Advertisement Revenue	2394 6 4		(2022 6 6)
	4010 5 3		(4076 3 3)
Less Expenditure—			
Printing Costs 2580 4 6			(2831 5 9)
Postages 334 7 8			(385 12 1)
Other Charges 398 5 2	3312 17 4	697 7 11	(465 11 7)
			(£393 13 10)
			(Excess of Expenditure over Income for 1939
		£6626 7 4	£1113 4 0)

AERONAUTICAL

Balance Sheet,

	£ s. d.	£ s. d.	£ s. d.
Share Capital—			
Authorised—40 Shares of 1/- each		2 0 0	
Issued—21 Shares of 1/- each fully paid			1 1 0
Royal Aeronautical Society Endowment Fund—			
Capital Account—Balance at 31st December, 1939 ...		51302 11 1	
Add Donations received during year		12935 13 6	
Entrance Fees received during year		409 10 0	
		64647 14 7	
Income Account—Surplus of Income over Expenditure for year to date...	346 19 9		
Less—Deficiency at 31st December, 1939	253 16 7	93 3 2	
			64740 17 9
Pilcher Memorial Fund—			
Capital Account—As at 31st December, 1939		99 14 0	
Income Account—Balance at 31st December, 1939 ...	31 7 0		
Add Income for year to date	4 0 8	35 7 8	135 1 8
Usborne Memorial Fund—			
Capital Account—As at 31st December, 1939		109 2 5	
Income Account—Balance at 31st December, 1939 ...	48 7 0		
Add—Income for year to date	3 19 0	52 6 0	161 8 5
Herbert Akroyd Stuart Fund—			
Capital Account—As at 31st December, 1939		688 19 0	
Income Account—Balance at 31st December, 1939 ...	250 8 7		
Add Income for year to date	23 18 0	274 6 7	963 5 7
R.38 Memorial Fund—			
Capital Account—As at 31st December, 1939		978 3 10	
Income Account—Balance at 31st December, 1939 ...	442 13 4		
Add Income for year to date	36 13 10	479 7 2	1457 11 0
Edward Busk Memorial Fund—			
Capital Account—As at 31st December, 1939		449 6 1	
Income Account—Balance at 31st December, 1939 ...	83 3 10		
Add Income for year to date	19 4 3	102 8 1	551 14 2
Wilbur Wright Memorial Fund—			
Capital Account—As at 31st December, 1939		1398 9 9	
Add Profit on Sale of Investment		21 18 0	
		1420 7 9	
Income Account—Balance at 31st December, 1939 ...	140 5 7		
Less Excess of Expenditure over Income for year to date	2 6 10	137 18 9	1558 6 6
Simms Gold Medal Fund—			
Capital Account—As at 31st December, 1939		250 0 0	
Less—*Income Account*—			
Deficiency at 31st December, 1939	31 0 6		
Less Income for year to date	12 19 0	18 1 6	231 18 6
Alston Memorial Fund—			
Capital Account—Donation received during year ...		250 0 0	
Less Legal Expenses *re* Formation		4 14 0	
		245 6 0	
Income Account—Income for year to date		2 3 7	247 9 7
			£70048 14 2

We report to the Members of Aeronautical Trusts Limited, that we have examined the above explanations we have required. We are of opinion that the Balance Sheet is properly drawn up December, 1940, according to the best of our information and the explanations given to us and as

3, Frederick's Place, Old Jewry, London, E.C.2
4th March, 1941.

TRUSTS LIMITED

31st December, 1940.

	£ s. d.	£ s. d.
Cash in Hand		1 1 0
Royal Aeronautical Society Endowment Fund—		
Leasehold Property at Cost—Less amount written off		
4, 8, and 9, Hamilton Place	11155 0 0	
Furniture at cost, *less* depreciation	3954 7	
Investments at Cost – £ s. d.		
£6474 11s. 7d. 3½ % Conversion Stock 6192 5 1		
£4500 3 % War Loan, 1955/59 ... ... 4497 0 2		
£15103 15s. 3d. 3½ % War Loan 14000 0 0		
£10000 2½ % National War Bonds, 1945/47 ... 10000 0 0		
£1000 3 % Defence Bonds 1000 0 0		
£629 16s. 4d. London County Council 2¾ % Stock, 1960/70 ... ... 600 0 0		
£2367 12s. 7d. Manchester 3 % Redeemable Stock, 1952/55 ... ... 2388 12 11		
£4100 London & North-Eastern Railway 3 % Debenture Stock 3162 6 3		
£3100 London, Midland & Scottish Railway 4 % Debenture Stock 3162 19 9	45003 4 2	
Cash at Bank	1370 17 8	
Amounts due for refund of Income Tax, etc. ...	5289 19 8	
	66773 9 0	
Less—Amount due to Aerial Science Limited ... 2028 7 3		
Amount owing for Legal Charges 4 4 0	2032 11 3	64740 17 9
Pilcher Memorial Fund—		
£115 6s. 10d. 3½ % War Loan at cost	116 5 0	
Cash at Bank	18 16 8	135 1 8
Usborne Memorial Fund—		
£113 3½ % War Loan at cost	114 11 1	
Cash at Bank	46 17 4	161 8 5
Herbert Akroyd Stuart Fund—		
£683 1s. 0d. 3½ % War Loan at cost	698 19 0	
Cash at Bank	264 6 7	963 5 7
R.38 Memorial Fund—		
£1048 11s. 2d. 3½ % War Loan at cost	1098 18 10	
Cash at Bank	358 12 2	1457 11 0
Edward Busk Memorial Fund—		
£284 4s. 2d. 3½ % War Loan at cost	284 4 2	
£217 London Transport 4½ % "A" Stock, at cost	199 4 6	
	483 8 8	
Cash at Bank	64 17 3	
Amount due for refund of Income Tax	3 8 3	551 14 2
Wilbur Wright Memorial Fund—		
£1246 18s. 1d. 3½ % Conversion Stock, at cost	1000 0 0	
£530 2½ % National War Bonds, 1945/47	530 0 0	
	1530 0 0	
Cash at Bank	46 10 0	
Amount due for refund of Income Tax	7 14 0	
	1584 4 0	
Less—Amount owing to Aerial Science Limited	25 17 6	1558 6 6
Simms Gold Medal Fund—		
£287 16s. 1d. India 4½ % Stock, 1958/68, at cost	250 0 0	
Cash at Bank	12 19 0	
	262 19 0	
Less—Amount owing to Aerial Science Limited	31 0 6	231 18 6
Alston Memorial Fund—		
£252 14s. 10d. 3 % War Loan, 1955/59, at cost	250 0 0	
Cash at Bank	2 3 7	
	252 3 7	
Less—Amount owing to Aerial Science, Limited	4 14 0	247 9 7
		£70048 14 2

Balance Sheet with the books of the Company and have obtained all the information and so as to exhibit a true and correct view of the state of the Company's affairs as at 31st shown by the books of the Company.

(Signed) PRICE, WATERHOUSE & CO

AERONAUTICAL

INCOME & EXPENDITURE ACCOUNTS

Royal Aeronautical Society

	£	s.	d.
To Legal Charges	53	10	0
,, Amortisation of Leasehold Property	485	0	0
,, Depreciation of Furniture	213	15	0
,, Surplus of Income over Expenditure for year carried to Balance Sheet	346	19	9
	£1099	4	9

Pilcher

To Income for year carried to Balance Sheet...	4	0	8
	£4	0	8

Usborne

To Income for year carried to Balance Sheet...	3	19	0
	£3	19	0

Herbert Akroyd

To Income for year carried to Balance Sheet	23	18	0
	£23	18	0

R.38

To Income for year carried to Balance Sheet	36	13	10
	£36	13	10

Edward Busk

To Income for year carried to Balance Sheet...	19	4	3
	£19	4	3

Wilbur Wright

To 1940 Award	60	0	0
	£60	0	0

Simms Gold

To Income for year carried to Balance Sheet	12	19	0
	£12	19	0

Alston

To Income for year carried to Balance Sheet...	2	3	7
	£2	3	7

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER, 1940.

Endowment Fund.

	£ s. d.
By Interest on Investments (less Tax)	931 1 11
,, Refund of Income Tax	168 2 10
	£1099 4 9

Memorial Fund.

By Interest on Investments (gross)	4 0 8
	£4 0 8

Memorial Fund.

By Interest on Investments (gross)	3 19 0
	£3 19 0

Stuart Fund.

By Interest on Investments (gross)	23 18 0
	£23 18 0

Memorial Fund.

By Interest on Investments (gross)	36 13 10
	£36 13 10

Memorial Fund.

By Interest on Investments (*less* Tax)...	15 16 0
,, Refund of Income Tax	3 8 3
	£19 4 3

Memorial Fund.

By Interest on Investments (*less* Tax)	49 19 2
,, Refund of Income Tax	7 14 0
,, Balance of Expenditure over Income for year carried to Balance Sheet	2 6 10
	£60 0 0

Medal Fund.

By Interest on Investments (gross)	12 19 0
	£12 19 0

Memorial Fund

By Interest on Investments (less Tax)...	2 3 7
	£2 3 7

(*Continued from page* 161.)

Censorship. There has been a considerable increase in the number and variety of papers published, and the Council would particularly like to acknowledge the ready help given by the N.A.C.A., the Institute of the Aeronautical Sciences and the Editors of American technical aeronautical journals to provide articles for the Journal.

The Income and Expenditure Account of Aerial Science, Limited, gives a summary of the expenditure on the Journal and sundry publications. The Income and Expenditure of the Journal is as follows (The figures in brackets are the corresponding figures for 1939):—

	£	s.	d.	£	s.	d.		£	s.	d.	£	s.	d.
Printing Costs ...	2580	4	6	(2831	5	9)	Sales	1615	18	11	(2053	16	0)
Postages... ...	334	7	8	(385	12	1)	Advertisements ...	2394	6	4	(2022	6	6)
Other Charges ...	398	5	2	(465	11	7)							
Profit	697	7	11	(393	13	10)							
	£4010	5	3	£4076	3	3		£4010	5	3	£4076	3	3

The accounts show a decrease in the sales, due to the stoppage of sales to all European countries, but a satisfactory increase in advertisement revenue. In 1939 the Journal for the first time showed an excess of income over expenditure. Despite the greater difficulties created by the war there is shown this year a greater profit than in 1939, £697 7s. 11d. as against £393 13s. 10d.

HONORARY TREASURER.

The Council record with the deepest regret the death of the Honorary Treasurer, Major D. H. Kennedy, O.B.E., F.R.Ae.S. Major Kennedy had completed nearly fourteen years as Honorary Treasurer of the Society and was for many years the Chairman of the Finance Committee. He was an indefatigable worker on behalf of the Society and seldom failed to attend meetings of the Finance Committee and the Council. Major Kennedy was largely responsible for directing the finances of the Society during the very difficult years of the financial slump.

OFFICERS OF THE SOCIETY.

The Council wish to place on record their appreciation of the work which has been carried on by the Honorary Officers of the Society.

Mr. A. N. D. Smith completes his thirteenth year as Honorary Accountant. During those years his advice has proved invaluable, particularly with regard to income tax and the general finances of the Society.

Mr. L. A. Wingfield, the Solicitor to the Society, continues to advise the Council on many important legal matters and in particular with problems arising out of war damage.

The Council particularly wish to place on record their appreciation of the services of the Grading Committee which has continued its work throughout the year. Every application for membership of the Society has been scrutinised with the point of view fully in mind that no candidate can be recommended for election unless he fully satisfies the rules.

STAFF.

The Council wish to place on record their high appreciation of the work and devotion to the Society's interests of the staff.

During the year there have been several hundred air raid warnings in the area in which the Society's headquarters are situated and many bombs have fallen in the immediate neighbourhood. The staff has continued the work of the Society throughout the raids without a break. Arrangements were made for

certain members to sleep on the premises in the early autumn, and later for a staff fire watch to be kept throughout each night.

It has not been possible for the Council and its Committees to meet as regularly as in peace time, and a greater responsibility has, therefore, fallen upon the staff during a time when conditions have been difficult, and with the added responsibility of protecting the building and its contents as far as possible.

OBITUARIES.

The Council record with great regret the deaths of the following members during the year:—

Mr. J. W. Copley, *Associate Fellow.*
Mr. T. McCowatt, *Companion.*
Sergeant G. T. Follows, *Student.*
Commander R. R. Graham, D.S.O., *Companion.*
Mr. H. Higgins, A.M.I.Mech.E., *Associate Fellow.*
Mr. J. M. H. Hoare, B.A., *Associate Fellow.*
Professor C. F. Jenkin, F.R.S., LL.D., M.Inst.C.E., *Fellow.*
Major D. H. Kennedy, O.B.E., *Fellow.*
Sergeant J. Lansdell, *Student.*
Pilot Officer C. M. Light.
Pilot Officer C. T. Locke, *Associate Fellow.*
Sergeant G. N. Fraser Luckie, *Graduate.*
Mr. W. J. M. Moss, *Student.*
Pilot Officer P. J. M. Nettleton, *Student.*
Flying Officer G. S. Ogilvie, B.Sc., *Associate Fellow.*
Mr. J. G. Olsen, *Associate Fellow.*
Mr. P. H. Rayner, *Associate Fellow.*
Flight Lieutenant R. C. Reynell, *Associate.*
Mr. Stanley Spooner, *Founder Member.*
Mr. E. A. Stroud, B.Sc., *Graduate.*

MAJOR D. H. KENNEDY, O.B.E., *Fellow.*

Major D. H. Kennedy was for nearly fourteen years the Honorary Treasurer of the Society. During those years he was a most active friend of the Society and one who never failed to give of his best in its interests. He was Chairman of the Finance Committee during those difficult years when the Society's income invariably failed to meet its expenditure, and it was largely due to his constant thought for the Society's welfare that it came through its crises so well. A week seldom passed by without a visit to the office, and he readily gave up his time to attend any meeting at which he thought his services could be of use.

From 1896 to 1916 he was an Associate Member of the Institute of Electrical Engineers and before the Great War was on the engineering staff of the G.P.O. In the war of 1914-18 he served in the R.F.C. and R.A.F., and from 1917 to 1923 was Assistant Director of Supplies (Technical) at the Air Ministry. In 1917 he was elected an Associate Fellow of the Society and a full Fellow in 1926.

PROFESSOR C. F. JENKIN, F.R.S., LL.D., M.Inst.C.E., *Fellow.*

By the death of Professor Jenkin, in October, engineering lost a very great figure, a great engineer who became a great teacher. He was that type of engineer who thoroughly understood theory and practice, from design to production. Educated at Edinburgh Academy & University and Cambridge University, he served as assistant to the works manager at Crewe Works, L.N.W.R., as Resident Engineer, Nettlefold's Steel Works, Assistant Works Manager, Siemens Brothers; works manager and himself head of the Railway Department among other posts. In 1908 he was appointed Professor of Engineering Science at Oxford, a post he held until 1929.

Professor Jenkin published many papers, but his name in aviation will always be remembered for his Report on the Materials of Construction Used in Aircraft and Aircraft Engines, in 1920, following his experience in the Royal Air Force during the Great War. This report has remained a classic of its kind, outstanding in its thoroughness and soundness.

STANLEY SPOONER, *Founder Member.*

Mr. Stanley Spooner died at the age of 83 on April 3rd, 1940, and with his death aviation lost one of its earliest and most enthusiastic pioneers. From his earliest years Mr. Spooner believed in the possibilities of flying. In 1900 he had a regular aviation section in the *Automotor Journal*, which he had founded four years previously. In 1908 he decided to produce a paper devoted solely to flying, and on January 2nd, 1909, appeared the first issue of *Flight*. The story of his struggles to keep the paper going, of his enthusiasm for the new art, and of his constant encouragement to all those interested in flying, has been told at length in the pages of his own paper.

Mr. Spooner was a Founder Member of the Society, whose activities he followed with the keenest interest. From the first days of his membership he gave it all the help he could in his own paper and in other ways, and on his death he bequeathed a sum of £5,000 to the Society, to be devoted to the foundation of a Stanley Spooner Scholarship for aeronautical research.

Of Stanley Spooner it can truly be said he was beloved by all and hated by none.

REVIEWS.

Plastics in Industry.

By "Plastes." Chapman and Hall, Ltd. 1940. 12/6 net.

The last twenty years has seen the rapid growth of a remarkable new industry, the plastics industry. Still in its comparative youth this new industry already holds out astonishing possibilities.

The book under review has been written to bring before industry as a whole the possibilities of plastics, and one might also add the impossibilities. The progress in plastics has been so rapid and so fruitful that it is not surprising to the uninitiated that one reads fantastic stories of completely moulded aeroplanes pouring out of giant presses faster than the expert women at Covent Garden can shell peas. This book will prove a wholesale corrective to the moulded aeroplane expert and will, at the same time, prove of the utmost value to those who are inclined to decry the future of plastics for constructional work. The excellent qualities of plastics are given equally with their limitations. As the authors say in their preface, "The plastics industry does not offer a ransom for all ills, nor a constructional material for all purposes. The secret with regard to plastics lies first in the fact that they are easily moulded into complicated shapes and, secondly, they possess many properties presenting outstanding advantages for many purposes."

The first few chapters are devoted to the various types of thermo-plastic and thermo-setting resins, moulding and fabrication technique, and engineering and chemical machinery and plant, and followed by chapters on the uses of plastics in the electrical, aeronautical, motor car, textile, building, and other industries. There is a chapter on synthetic glues and one on synthetic rubber.

So much for a general summary of the contents of the book. It can be said at once that it is impossible to go into detail, for such an astonishing field is covered, and covered in a most interesting and informative way, that no one, whatever his knowledge of plastics may be, will fail to learn something of value. To those who are manufacturers of any types of goods the book is thoroughly recommended for reading, as undoubtedly if they are not already making use of plastics in some form or other, they will undoubtedly find a means of doing so.

Of most interest to aircraft engineers is the chapter dealing with aircraft construction. To quote the opening words of the chapter, "Robbed of all sensationalism, the rôle of plastics in aircraft construction is a most important one."

The authors point out that it is a somewhat lamentable fact that aircraft designers and draughtsmen have a very meagre knowledge of plastics. Yet the usage is extensive and the materials even in one class varied in their characteristics. "Take, for instance, the phenolic moulding resin. Mechanical properties may range from 4,000 to 11,000 lb. per sq. in. tensile strength with a wood filler; 4,000 to 10,000 with a mineral filler; 6,500 to 8,000 with a macerated fibre filler."

It is true that extensive use is being made of plastics, but a still wider use can undoubtedly be made of these new materials, at an immense saving of time. The authors draw particular attention to impregnated woods and the work of

de Bruyne on reinforced plastics. Dr. de Bruyne's material Gordon Aerolite has a specific gravity of half that of duralumin, a tensile strength of 45,000 lb./in.^{2} compared with 55,000 of duralumin, and a compressive strength of 24,000 lb./in.^{2} compared with 55,000 of duralumin. The shear strength is 5,000 as against 30,000 lb./in.^{2} of duralumin, and E_1 6.0×10^6 as against 10.0×10^6. These are the figures published in the book, though they have been considerably improved upon since. On a strength for weight basis the latest flax reinforced phenolic resins are serious competitors with the light alloys. Dr. de Bruyne claims, indeed, that in the range of long struts, thin struts and lightly loaded struts the organic material is supreme. Where these plastics can be used for stressed parts they can be used to the greatest possible advantage, in that they can be easily shaped to suit the conditions of loading where such shaping in metal would be costly and difficult.

ELEMENTARY AERODYNAMICS.

D. C. M. Hume, A.F.R.Ae.S., M.E.I.C., A.F.I.Ae.S. Pitman and Sons, Ltd. 1941.

There is a definite dearth of elementary text books on Aerodynamics, introductions as it were to this subject, and the one under review is all the more welcome for that reason alone.

Group Captain D. C. M. Hume, of the Royal Canadian Air Force, was in the Royal Naval Air Service during the war of 1914-18 and has been immersed in aviation ever since. For many years he was training the young Canadian aviation enthusiasts in the way they should go, and this book is a result of his experience of what it is and what it is not necessary to know in aerodynamics to get a sufficient grasp of it to be of value without necessarily being an expert.

Let it be said at once that the book is an excellent introduction to its subject, well and clearly written and to the point. It contains a most useful digest at the end of each chapter of that chapter. It must be emphasised that it is only an introduction, the kind of book which is wanted by those who may be mainly concerned with stressing and other problems, so that they can get that useful though elementary knowledge of aerodynamics which is necessary for the understanding of any flight problem, constructional, or otherwise. For those who intend to specialise in aerodynamics this is the kind of book which they should read first.

Aerodynamics has now reached such a stage of mathematical complexity in many ways that a prospective student may easily be frightened off the subject when he surveys some of the more modern books on aerodynamics. Unfortunately, so many teachers have forgotten their own uncertain and nervy steps at the bottom of the stairway of knowledge that they expect their own students to jump up half the steps in a bound and feel a little resentful if they are out of breath or a little uncertain on which step they have landed in consequence. There are far too few books written of the type under review and far too many teachers who are prepared to pull such books to pieces on the grounds of happy-go-lucky descriptions and statements, which are after all human, in place of such rigid accuracy that is not always understandable.

One likes, for example, Group Captain Hume's statement, "A turn is a continuous persuasion from a straight path." Talking of spinning, after explaining its causes and cure, the author ends with the perfectly sound statement, "When in difficulties kick your rudder."

The book finishes with a series of test questions and answers to check the reader's knowledge. Examples of these questions are: "By which of the following is the absolute ceiling of an aircraft diminished?

(*a*) Flight at the equator.
(*b*) Use of a fixed airscrew in place of a V.P.
(*c*) Streamlining all engine parts.
(*d*) Using wing flaps.
(*e*) Changing the engine for one of larger h.p. producing the same power loading."

THE MILITARY AEROPLANE.

E. Colston Shepherd. Oxford Pamphlets of World Affairs, No. 44. Clarendon Press. 1941. 3d.

This is the latest pamphlet to be issued by the Clarendon Press in that most excellent series the Oxford Pamphlets on World Affairs. Anyone who has a set of these pamphlets and has thoroughly digested the information set out in them, will have a knowledge of the present conflict, its causes, and the possibilities and probabilities of the future, which will enable him to follow intelligently the intricate moves which are being made weekly in political, military and economic fields. The Clarendon Press have done an excellent service publishing these pamphlets at a price which gives no one an excuse to plead ignorance on some particular aspect of the present situation.

Each pamphlet has been prepared by an authority on the subject. The one under review is by the Editor of the *Aeroplane*, who for some years was the air correspondent of *The Times*. It is the second one he has written in the series, the first (No. 28) dealing with Britain's air power.

Mr. Shepherd writes with knowledge, and writes with a sense of responsibility of the meaning of words which makes for pleasant reading and clear expression. Here Mr. Shepherd explains the various functions of the different types of aircraft, the fighter, bomber, reconnaissance machine, dive and torpedo bombers, and others. He shows what is expected from each and what developments of each may be expected as the war progresses. There are hints of machines to come which almost take away the breath of one who thought in the 1914-18 struggle of 150 m.p.h. as a speed to be reached only by stupendous effort. Here, for example, is a quotation from Mr. Shepherd's book on the ideal fighter.

"It would be one about 50 m.p.h. faster than the best bomber and armed with eight small cannon able to fire shells at the rate of 600 a minute each for a period of about three minutes. If to these characteristics could be added a range of 2,000 miles, an initial rate of climb of 4,000 feet per minute and a ceiling of 45,000 feet, then the lucky air force would have obtained an instrument which would take the heart out of its opponents. Before the war is over there may be such a fighter."

If such a fighter materialises then one must disagree with the last sentence of Mr. Shepherd's pamphlet: "And since it is the bomber and not the fighter which wins an air war, the bomber must set the pace."

WAVES. A MATHEMATICAL ACCOUNT OF THE COMMON TYPES OF WAVE MOTION.

C. A. Coulson, M.A., Ph.D. Oliver and Boyd. 1941. 5/- net.

This is the latest publication in the University Mathematical Texts series, a publishing enterprise for which only the highest praise can be given. In this excellent series, published at such a reasonable price, students have an opportunity of obtaining the fundamental knowledge required for a degree course in Applied Mathematics or Natural Philosophy. This series naturally calls for the most careful editorship and writing, for each book in the series, specialised though it is, covers a field which usually calls for text books of considerable size and at a price which comes hard on the pocket of the student. Most of

these text books, too, contain much matter which could be left out as far as fundamental grounding is concerned.

The University Mathematical Texts contain just that amount which is necessary and no more for the student to obtain a sound grasp of his subject. The book under review on Waves is excellent in that respect. It is, indeed, first class in that it brings together so many types of wave motion which it would require half a dozen text books normally to expound.

Chapter I expounds the standard equations of wave motion. To quote from the first paragraph: "In the following chapters we shall find that whatever the nature of the medium which transmits the waves, whether it be air, a stretched string, a liquid, an electric cable, or the ether. . . . They are all governed by a certain differential equation, the Equation of Wave Motion, and the mathematical part of each separate problem merely consists in solving this equation with the right boundary conditions, and then interpreting the solution appropriately."

The chapters which follow show the application and solution of the fundamental equation for waves on strings, in membranes, longitudinal waves in bars and strings, in liquids, sound waves, and electric waves. There is a final chapter on general considerations. Each chapter is followed by examples and answers. The author is to be congratulated on the clarity and conciseness of his text and the publishers on the excellence of their printing. It is to be hoped that this series will be continued to cover all the requirements of students, and one would like to see, on the same lines, a University Engineering Texts.

DEFENCE AGAINST THE NIGHT BOMBER.

N. Pemberton-Billing. R. Hale, Ltd. 1941. 2/6 net.

Pemberton-Billing has courage, imagination, and an odd experience of aviation, three things which do not necessarily amalgamate to produce a defence against the night bomber. As a pioneer of flying, as a constructor of aircraft with novel ideas which rarely went into second editions, and as one who undoubtedly has the cause of this country close to his heart, he must be listened to, with interest, if nothing else. Those who have had the astonishing experience of knowing him, indeed, will know how difficult it is not to listen to him.

There are times when the author talks or writes such sound sense that it seems a pity to have it completely overlaid, if not smothered, by the nonsense which he noises abroad. Pemberton-Billing has that knack of being exasperating when he is not amusing and of being amusing when he is not exasperating. It makes a man interesting, but it does not make him logical.

Chapter I begins: "There is a defence against the night bomber. As the Government, either through incompetence or lack of imagination, or a fatal combination of both, refuse to make any attempt at seriously tackling its most vital problem, the only course left to one is to make an appeal to the imagination and reason of the people in an endeavour to obtain the support of intelligent public opinion."

Back P.-B. and you are intelligent. Don't back him and you are incompetent and lack imagination. One wonders which view the German High Command will take after reading the book, for they have their problems of the night bomber, too. The author is cautious enough to say that suggestions of great value to this country may be of very little benefit to the enemy.

Let us examine the author's proposals in detail. First of all he has no use for the barrage balloon, by day or night. His attitude towards anti-aircraft defence at night is summed up by the following quotation from Chapter II: "Possibly the best definition of this form of defence is that given by an A.A. gunner, who reported that he had spent the whole night firing at nothing and

hitting it every time." The author is sure that a profit and loss account of the A.A. barrage would be " confined entirely to the subject of loss " and " the Germans should pay an entertainment tax for the Brock's Benefit that we put up for them so regularly."

There are pages of this kind of Pemberton-Billingsgate. Chapter III is concerned with night fighters.

" The fighter has proved itself to be the only effective defence against the night raider, and it is only by increasing the ability of the night fighter to remain in the air and to find and overtake the raider that we can hope to take any toll of the enemy's bombers or afford this country adequate defence by night."

That's more reasonable.

But his suggestion to drop 400 lb. naval depth charges from British aircraft on the German night bombers is fantastic rubbish.

Chapter IV is the author's summary of why the black out should be abolished. I present the whole of his arguments to the Germans for careful study. Nothing would please our bomber pilots more than to find Cologne and Berlin and a hundred other German cities well lighted. Chapter V deals with " lights up." Here, of course, the author is brilliant. He proposes to light up the whole of England by searchlights " pointing upwards over the whole country, so that England presents to the enemy raider nothing but a confused and frightening mass of lights, behind which nothing can be seen."

It will cheer the Home Guard to know that, in the author's opinion, " the watching and maintenance of these lights would provide a worth while and intelligent occupation." The author certainly throws a light on Home Guard intelligence.

The tow fighter appears in Chapter VI, a formidable aeroplane which " carries in its nose a pair of retractable jaws." Not, mark you, for biting the German bombers in half, but to bite the tails of our own bombers and hang on and be towed. Even Pemberton-Billing admits the scheme is revolutionary. The slip-wing fighter of Chapter VII is really the Mayo composite disguised; as is the slip-wing bomber of the next chapter.

The rest of the book is not actively concerned with the title, and calls for no comment therefore.

THE TECHNOLOGY OF MAGNESIUM AND ITS ALLOYS.

F. A. Hughes and Co., Ltd., London. 30/- net. 1941.

This is a translation by the technical staffs of F. A. Hughes and Co. of " Magnesium und seine Legierungen," compiled by Dr.-Ing. E. h. Adolf Beck.

The German original, a compilation by various authors under the general direction of Dr. Beck, was the first book to gather together the great mass of information on magnesium now in existence.

The authors of this book are the men who have spent years developing this remarkable metal and as pioneers who have literally forced their way through dense clouds of prejudice and criticism, they have a certain amount of right to lay down the law, though their laws do not always agree with those of magnesium technologists in other countries.

The book is a monumental survey, from the raw materials and production, of the meetal, through its physical properties and mechanical properties, to its manufacture, processing, uses, and its alloys.

As late as 1933, when the Council announced a lecture by Dr. Aitchison on " Light Alloys for Aeronautical Purposes, with Special Reference to Magnesium," there were many of the opinion that magnesium had not arrived at the state when it was worth while seriously considering it. In the discussion which

followed Dr. Aitchison's lecture there were caustic criticisms of the lecturer's obvious enthusiasm for the future of the metal.

Three years later the Council invited Dr. Desch to lecture on " Magnesium Alloys." Dr. Desch began his paper by a reference to Dr. Aitchison's paper, and said: " Since that date, the interest of aircraft constructors in magnesium has greatly increased." Since Dr. Desch's paper was published that interest has been increasing still more rapidly and magnesium alloys are being more and more used in aircraft construction.

Dr. Pye opened the discussion on Dr. Desch's paper and now contributes a Foreword to the volume under review, and he stresses the change of attitude towards the metal in the last few years " from the position of being a curiosity metal to one of vast industrial and military importance." Such a tribute, coming from the Director of Scientific Research at the Ministry of Aircraft Production, is significant.

This book must prove of the utmost value to all those concerned with the manufacture and use of magnesium, despite some defects of having been written from the German point of view with a bias for German references. Much of this has been corrected by the translators and additional references added throughout. It is interesting to note that footnotes on pages 140 and 252 refer to Aitchison's and Desch's papers read before the Society.

F. A. Hughes and Co., Ltd., are to be congratulated in full measure for their enterprise in publishing such an excellent translation with valuable footnotes to the text. The printing has been beautifully done by the Kynoch Press, a task of no mean order when it is realised there are over 500 illustrations in the book and nearly one hundred tables.

RELAXATION METHODS IN ENGINEERING SCIENCE.

R. V. Southwell, F.R.S. Oxford: Clarendon Press. 1940. 17/6 net.

There has been much talk of " Relaxation Methods " during the last few years, so that an introductory volume on the subject by Professor R. V. Southwell is most welcome.

The book is specially valuable as it gives, along with certain entirely new matter, the gist of the series of papers which he and his special group of workers have published during the last five years.

" Relaxation," it would seem, is somewhat like playing the piano; the art can only be acquired by practice.

The engineer must have in his kit bag a number of different tools and he must be familiar with the salient features of each. His skill lies in his choice of tool for the particular job in hand. If the job happens to be a problem in redundant structures, he has already at his disposal (to mention only a few) the Strain-Energy method, the Slope-Deflection method, the Hardy Cross Moment Distribution method, the Müller-Breslau displacement relationships which may be used either in conjunction with Williot-Mohr diagrams or with celluloid models of the structure. Help is often afforded by superposition, but each method has its limitations. The precise technique and set out of his tools must be left to the worker—that which, owing to some personal idiosyncracy, he finds most useful for speedy manipulation and the production of results. He will, however, generally find that it pays in the long run to adhere to certain standard set outs which have been evolved, not in relation to his particular problem, but for use in problems of greater complexity. In this way, if greater complexity is introduced, he will not be confronted with difficulties in change of technique just when he requires to concentrate his efforts on pushing the problem through. Two fingers may suffice to obtain results of a sort from the piano or the typewriter, but it is wiser at once to master a sound technique devised by an

expert who has visualised possibilities far beyond the tyro's present needs or understanding.

It is somewhat in this spirit that the reader should approach the new tool of "Relaxation" which proclaims itself capable of providing an approximate solution to any and every problem in mathemathical physics which involves a minimal theorem—the degree of approximation being entirely in the hands of the operator.

In the field of structures, in relation to which it was first developed and in relation to which the technique is developed in the opening chapters of the book, the practical limitations to the application of Relaxation methods comes from the *number of joints* in the structure, since each joint requires a separate set out and beyond a certain limit manipulation becomes unwieldy. The author, from his experience, puts the practical limitation at about twenty joints. Within this limit the problem can be tackled and, what is more, degree of redundancy has little effect upon the complexity of the work; it only affects the time expended in preparing certain preliminary tables. Rigidity or flexibility of the joints is likewise only a minor consideration.

The way is opened by considering simple displacements and the forces involved by such displacements. Preliminary tables are constructed to cover the range of all possible types of displacement. These tables can then be manipulated in such a way as to leave less and less margin between the configuration achieved and the configuration desired (generally that which involves a given system of external forces). As the author remarks: "The main features of the distortion will usually be intuitively evident to an experienced engineer; the Relaxation Method seems to be alone in permitting him to use his intuition without putting undue trust in its accuracy."

Since this is also an approximate method, it may be asked, "In what way does it differ from that of Hardy Cross?" In one case—that of continuous beams—there is no fundamental difference. The difference, as the author states, is purely the superficial one of set out, and precisely the same results will be obtained by the use of either method. In regard to frameworks, since Southwell originally devised his Relaxation method to deal with pin-jointed structures, subject only to primary stresses and later developed the method to take account of secondary stresses, due to stiffness of the joints, Relaxation method includes all possible types of joint deformation, whereas Hardy Cross, who originally devised his method to deal with rigid jointed structures in which the secondary stresses are all important, made the usual assumptions that deformations due to shear and direct stress and also the effect of direct stress upon the flexure of a member, are negligible. Whether or no they are negligible in a particular problem will, of course, be an important point to consider when selecting the tool for the job. But it will be realised that when the method is extended to deal with minimal problems in other branches of mathematical physics it may be of the utmost importance that the analogue of "joint displacement" should be completely and correctly accounted for.

It has been said that it is only by practice that the art of Relaxation can be acquired, and it is only by doing the "homework" with which the earlier chapters are liberally besprinkled that the reader can hope to grasp the finer points in the technique. The book is well arranged in growing order of complexity, much in the same order as the original papers appeared from which most but not all, the contents of the book have been drawn. The range is roughly: Pin-jointed frameworks; continuous girders, including continuous beams under transverse loading combined with end thrust; plane frameworks having rigid joints; the general problem of space frameworks; theoretical aspects of Relaxation methods; application to electrical networks and gyrostatic systems; details of technique in application to natural modes and frequencies of vibrating systems; forced oscillations and dissipative forces; problems of equilibrium, elastic stability and vibrations; further developments; non-linear systems.

In each chapter the reader is provided with sufficient background to enable him to appreciate the value of the new method as an alternative to methods already available. At the end of each chapter there is a short recapitulation and a list of references to papers discussed in that chapter.

The book is very readable, viewed simply as an introduction to minimal problems in mathematical physics, but the reader should be prepared to sit down with sheets of foreign money analysis paper (see footnote on p. 16), and to give himself up, for the time being, to routine practice and to thinking along Relaxation lines. Otherwise he will gain very little from his reading. He will be rewarded with an understanding of a brilliant new tool in certain fields of knowledge, even if for the present he cannot make very much use of it in his own.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES.

MAY, 1941.

Wilbur Wright Memorial Lecture.

The 29th Wilbur Wright Memorial Lecture will be given by Mr. J. T. Trippe, M.A., President Pan American Airways Inc., on Thursday, May 15th, at 6.30 p.m., in the Lecture Theatre of the Institution of Electrical Engineers, Victoria Embankment, W.C.2. The subject of the lecture will be "Ocean Air Transport."

Associate Fellowship Examinations.

The next Associate Fellowship Examinations will be held on Wednesday, May 21st, and Thursday, May 22nd, 1941, and the Library will be closed on those days. Full particulars will be sent direct to candidates who have entered for the examination.

Journal Envelopes.

It will be appreciated if members from time to time would retain the envelopes in which the Journal has been posted to them so that they can be used again during the present paper shortage.

Election of Members.

Associate Fellows.—Sydney Breedon Bailey, Raymond Arthur Clare, William Davidson (from Student), Stanley Dearing (from Graduate), Harold Goodwin, Denis Alban James Harben (from Student), John Trueman Henshaw, David Matthew McElhinney (from Student), Charles Peter Plantin (from Graduate), Stuart Russell Proctor, Richard Christopher Sowerbutts.

Associates.—Josiah Louis Beilschmidt, Jesse Stanley Hart, John Roger Le Claire, Reginald Henry McGibbon, Frank Percival Shepherd, William Morey Simms, Albert James Willmore.

Graduates.—George Robert Brailsford, Herbert Maynard Hackett (from Student), John Douglas Hamilton, Tom Joseph Percival Joy, George Edward Otter (from Student), David Edward Parker, Roy Ernest Vaughan-Stainton (from Student), John Keri Williams.

Students.—David Bernzweig, Peter Eugene Bish, George Anthony Dawson, George William D. Gallia, John Cecil Gibbings, Colin Richard Frederick Gray, Lloyd Archibald Hales, Richard George Harvey, Jack Lenard Higgins, Raymond Holl, Joseph James Lewis, Edward Charles Hamilton Ryley, Derrick Edward Joseph Tipping.

Companions.—William Arthur Edwards, Marie Zbigniew Krzywoblocki, John Aleander Maurer, Stanley Francis Potter, Walter Jack Ruck.

Additions to Library.

Pamphlets in italics, with location reference following in brackets.
Books marked * or ** may not be taken out on loan.

A.a.234.—Mechanics of Flight. (4th Edition.) By A. C. Kermode. Sir Isaac Pitman. 1940. 8/6.

B.f.81.—*Birds and the Wind. By N. T. McMillan. Smithsonian Institution, Washington. Reprint No.* 3,571. 1940. (Y.30.ii.53.)

*B.g.100.—Aircraft of the Fighting Powers. By H. J. Cooper and O. G. Thetford. (Ed. by D. A. Russell.) Harborough Publishing Co. 1941. 10/6.

BB.d.29.—Aircraft Hydraulic Equipment. (2nd Edition.) By R. H. Bound. Dowty Equipment, Ltd. 1940.

BB.e.8.—*The Junkers Works. Junkers Flugzeugwerke. (Abt.* 1921.) (Y.33/4a.)

BB.e.29.—*Führer durch Junkers-Flugzeugwerke, A-G. Junkers Flugzeugwerke. (Undated.)* (Y.33/67.)

D.b.162.—*Modern Trends in Air Transport. By W. F. Durand. Smithsonian Institution, Washington. Reprint No.* 3,581. 1940. (Y.30.ii.54.)

D.c.84.—*Papers read at Conferences of the Aerodrome Owners' Association,* 1936-38. (File case.)

**D.c.85.—Airports. By John Walter Wood. Coward, McCann, Inc. (U.S.A.). 1940. $12.50.

EE.c.61.—Aircraft Engines. Vol. II. By A. W. Judge. Chapman and Hall. 1941. 30/-.

EE.j.31.—*Unsoundness in Gravity Die-Cast Silicon-Aluminium Alloy Pistons. By R. T. Parker. Institute of Metals. (Reprint from Journal, Vol.* 67, *Part* 3. 1941. (PEE.3.c.7.)

G.e.J.16 and 17.—The Technology of Magnesium and its Alloys. By Dr. A. Beck. F. A. Hughes and Co., Ltd. 1941. 30/-. (Two copies.)

I.c.17.—Mathematical Methods in Engineering. By Th. von Karman and M. A. Biot. McGraw Hill. 1940. 28/-.

J.g.183.—*Physical Interpretation of the Weather. By Edgar W. Woolard. Smithsonian Institution, Washington. Reprint No.* 3,562. 1940. (Y.30.ii.51.)

J.g.184.—*Hurricanes into New England: Meteorology of the Storm of September 21st,* 1938. *By Charles F. Brooks. Smithsonian Institution, Washington. Reprint No.* 3,563. (Y.30.ii.52.)

L.a.40.—The Civil Air Guard Book. By Malcolm Logan. Nicholson and Watson. 1939. 3/6.

L.c.19.—Anleitung zur durchführung von Flugversuchen. Band I. Junkers Flugzeugwerke. 1929.

L.j.86.—*Modern Uses of Aerial Photography. Junkers Flugzeugwerke. (Undated.)* (Y.16/19.)

M.a.23.—*Inaugural Address to the Institution of Electrical Engineers, Oct. 24th,* 1940. *By J. R. Beard. (Reprinted* 1941.) (Y.18.b.6.)

M.c.25.—Elementary Handbook for Wireless Operators. By W. E. Crook. Sir Isaac Pitman. 1941. 4/-.

S.b.99, 101.—*Parliamentary Debates: House of Commons Official Report, Vol.* 368, *No.* 22. *Feb. 6th,* 1941, *Vol.* 369, *No.* 35. *March 11th,* 1941. (Y.20.ii.)

S.b.100.—*Public Account. (Air Votes,* 1939.) (Y.20.ii.)

S.b.102.—The Royal Air Force. By F. V. Monk and H. T. Winter. Blackie and Son, Ltd. 1939. 4/-.

S.e.21.—*Air Raid Precautions Training Bulletin, No. 1. Ministry of Home Security.* 1941. (PS.3.b.7.)

*S.e.22.—*The Battle of Britain. Ministry of Information. H.M.S.O.* 1941. 3*d*. (PS.3.a.10.)

T.a.85.—*Obituary Notices of Amy Johnson. (Special number of "The Woman Engineer," March,* 1941.) (Y.5.J.)

T.a.86.—*Souvenir of the Ceremony of Unveiling the Lawrence Hargrave Memorial, Stanwell Park, New South Wales. (Privately printed,* 1940.) (Y.5.H.)

UH.3.—*Atti di Guidonia, No. 36.*

Sulla Determinazione sperimentale dei Momenti d'Inerzia. By Dr. Pietro Teofilato. 1940. Lire 3.

UU.b.2c and 3b.—(*National*) *Advisory Committee for Aeronautics.* 2nd Annual Report (1916); 3rd Annual Report (1917). (Bound volumes, duplicates.)

*UU.c.—*National Advisory Committee for Aeronautics: Technical Memoranda*:—

No. 942. On the Theory of Unsteady Planing and the Motion of a Wing with Vortex Separation. By L. Sedov. (From C.A.H.I. Transactions, No. 252, 1936. Moscow.)

No. 943. Tests of Lead-Bronze Bearings in the D.V.L. Bearing-Testing Machine. By G. Fischer. (From Luftfahrtforschung, July, 1939.)

No. 944. Italian High-Speed Airplane Engines. By C. F. Bona. (Volta Meeting, 1935.)

No. 945. Experiments on Ball and Roller Bearings under Conditions of High Speed and Small Oil Supply. By G. Getzlaff. (From Jahrbuch 1938 der Deutschen Luftfahrtforschung.)

No. 946. Experimental Results with Airfoils Tested in the High-Speed Tunnel at Guidonia. By A. Ferri. (From Atti di Guidonia, No. 17, 1939.)

No. 947. New Equipment for Testing the Fatigue Strength of Riveted and Welded Joints. By W. Müller. (Schweizer Archiv. No. 10, 1937.)

No. 948. A Simple Approximation Method for obtaining the Spanwise Lift Distribution. By O. Schrenk. (From Luftwissen, April, 1940.)

No. 949. The Maximum Delivery Pressure of Single-Stage Radial Superchargers for Aircraft Engines. By W. von der Nüll. (From Luftwissen, May, 1940.)

No. 950. Buckling Tests with a Spar-Rib Grill. By Josef Weinhold. (From Luftfahrtforschung, March, 1940.)

No. 955. The Cause of Welding Cracks in Aircraft Steels. By J. Müller. (From Luftfahrtforschung, April, 1940.)

No. 956. Corrections on the Thermometer Reading in an Air Stream. By H. J. Van Der Maas and S. Wynia. (From National Luchtvaartlaboratorium, Amsterdam, 1939.)

No. 957. Resonance Vibrations in Intake and Exhaust Pipes of In-Line Engines. By O. Lutz. (From Luftfahrtforschung, April, 1940.)

No. 958. General Relationships between the various systems of Reference Axes employed in Flight Mechanics. By H. J. Rautenberg. (From Luftfahrtforschung, April, 1940.)

No. 959. Note on the Calculation of Boundary Layers. By L. Prandtl. (V.D.I. Reprint from Z.A.M.M., Feb., 1938.)

No. 960. Creep Strength of Stabilised Wrought-Aluminium Alloys. By W. Müller. (Aluminium-Industrie, Neuhausen, Switzerland; Dec., 1939.)

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THE FLOW OF A PERFECT FLUID THROUGH CASCADES OF AEROFOILS.

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Summary.

The paper contains a generalisation of the conformal transformation by means of which a circle is converted into Joukowski aerofoils. The transformation is applied to a cascade of oval bodies which is the corresponding generalisation of the isolated circle; and it converts the oval bodies into a wide variety of cascades of curved shapes, which are generalisations of the isolated Joukowski aerofoils. In one particular case, the transformation yields a grid of flat laminæ. Since the perfect fluid flow through such a grid is known (it appears to have been first given by Joukowski) the perfect fluid flow past the ovals, in any direction, and with equal but otherwise arbitrary circulation round each, is obtained. Accordingly, the perfect fluid flow through any of the derived cascades can be obtained.

The paper commences with a statement of the equations of flow through the grid of flat laminæ. The transformation of a single flat lamina into a circle is then given, and is followed by an exposition, by parallel methods, of the relation between the grid of flat laminæ and the cascade of oval bodies. The usual transformation of an isolated circle into a circular arc and into Joukowski aerofoils is stated, and the corresponding process of conversion of the cascade of ovals into cascades of aerofoils follows.

Much of the work relates to the incidental but necessary consideration of the positions of the singularities of the transformation in relation to the transformed bodies. Formulæ are given which are helpful in numerical computation; a graphical method of solution is also developed. The type of body derived by the method is shown in the diagrams, in which it is to be remembered that each body repeats at intervals of π along the imaginary axis. In certain cases, the bodies are re-entrant, and these are therefore of no practical importance. In other cases, thin curved laminæ, which are generalisations of a circular arc, result. There are also, however, a number of examples of bodies of conventional aerofoil shape.

The paper concludes with the consideration of the perfect fluid flow through certain of the cascades when the Kutta-Joukowski condition is applied to each member; a formula for the lift coefficient on each aerofoil is also found.

The work has been carried out in the Aerodynamics Department of the National Physical Laboratory, and it is published on the recommendation of the Aeronautical Research Committee and by permission of the Director of the Laboratory.

Summary of Principal Formulæ.

The transformation connecting the l-plane and the z-plane ($l = m + in$, $z = x + iy$) is

$$\tanh l \tanh\left(\frac{z-l}{e^{2i\sigma}}\right) = \tan^2 \frac{a}{2}, \quad 0 \leqslant a \leqslant \frac{\pi}{2}$$

This transformation is applied to the cascade of l-plane ovals

$$\cosh 2m = \sec b \cos 2n, \quad a \leqslant b \leqslant \frac{\pi}{2}$$

or to the same ovals so displaced that the cascade axis remains parallel to the imaginary axis and that all the singularities of the transformation remain within the ovals. The flow round the ovals is defined by the equation

$$\left(\frac{\tanh^2 l-\tan^4 b/2}{1-\tan^4 b/2}\right)\frac{dw}{dl}=U\left(\frac{\tanh^2 l-\tan^2 b/2}{1-\tan^2 b/2}\right)-iV\left(\frac{\tanh^2 l+\tan^2 b/2}{1+\tan^2 b/2}\right)+iW\tanh l,$$

where U and V are the velocity components at infinity parallel respectively to the real and imaginary axes, and the circulation round each oval is $2\pi W$, leading to velocity components $\pm W$ at infinity parallel to the imaginary axis.

The spacing of the resultant cascade in the z-plane is π; the chord of the skeleton of each aerofoil is

$$c=2\{\cos\sigma\sinh^{-1}(\tan a\cos\sigma)+\sin\sigma\sin^{-1}(\sin a\sin\sigma)\},$$

while the angle between the real axis and the chords of the skeletons of the aerofoils, *i.e.*, the stagger, is σ.

§ 1. Two-Dimensional Flow Through a Grid.

Consider the flow in the ζ-plane represented by

$$u-iv=\frac{dw}{d\zeta}=\frac{U\sinh\zeta+iW\cosh\zeta}{\sqrt{(\sin^2 a+\sinh^2\zeta)}}-iV \quad . \quad . \quad . \quad (1)$$

where $0\leqslant a\leqslant\pi/2$. The term $-iV$ represents a uniform flow of velocity V parallel to the positive direction of the η axis. Moreover, on the η axis, equation (1) reduces to

$$u-iv=\frac{iU\sin\eta+iW\cos\eta}{\sqrt{(\sin^2 a-\sin^2\eta)}}-iV \quad . \quad . \quad . \quad . \quad (2)$$

When $\sin^2 a>\sin^2\eta$, the radical in (2) is real, and the whole term is therefore imaginary. There is thus no flow across the parts of the η axis defined by $\sin^2 a>\sin^2\eta$. For the remaining parts of the axis, that is, those for which $\sin^2\eta>\sin^2 a$, the radical in (2) is purely imaginary, and the flow involving the U and W terms is accordingly normal to the η axis.

Equation (1) therefore represents the flow through a grid of equal laminæ distributed periodically along the η axis; the laminæ are those parts of the axis for which $\sin^2 a>\sin^2\eta$. The length of each lamina is thus $2a$, and the period with which they appear is π. The grid is illustrated in Fig. 1.

Equation (2) shows that the flow due to the U term alone has stagnation points when $\sin\eta$ vanishes, *i.e.*, at the centre of each lamina. On the other hand, the flow due to the W term is continuous along each lamina and has a stagnation point in the middle of each gap.

At very large distances from the η axis, $\sin^2 a$ becomes negligible in comparison with $\sinh^2\zeta$ and (1) then reduces to

$$\frac{dw}{d\zeta}=U+iW\coth\zeta-iV \quad . \quad . \quad . \quad . \quad . \quad (3)$$

so that at $\xi=+\infty$,

$$\frac{dw}{d\zeta}=U-i(V-W). \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and at $\xi=-\infty$

$$\frac{dw}{d\zeta}=U-i(V+W). \quad . \quad . \quad . \quad . \quad (5)$$

These components of velocity are also illustrated in Fig. 1. There is an ambiguity in the sign of the radical which corresponds to the fact that, subject to continuity along any streamline, the direction of flow may be reversed, and in particular to the fact that on the laminæ the flow due to the terms involving the radical will have opposite directions on the front and back faces. It is now evident that (1) represents the flow through the grid of laminæ due to a uniform flow of velocity V in the positive direction of η, a uniform flow of velocity U at

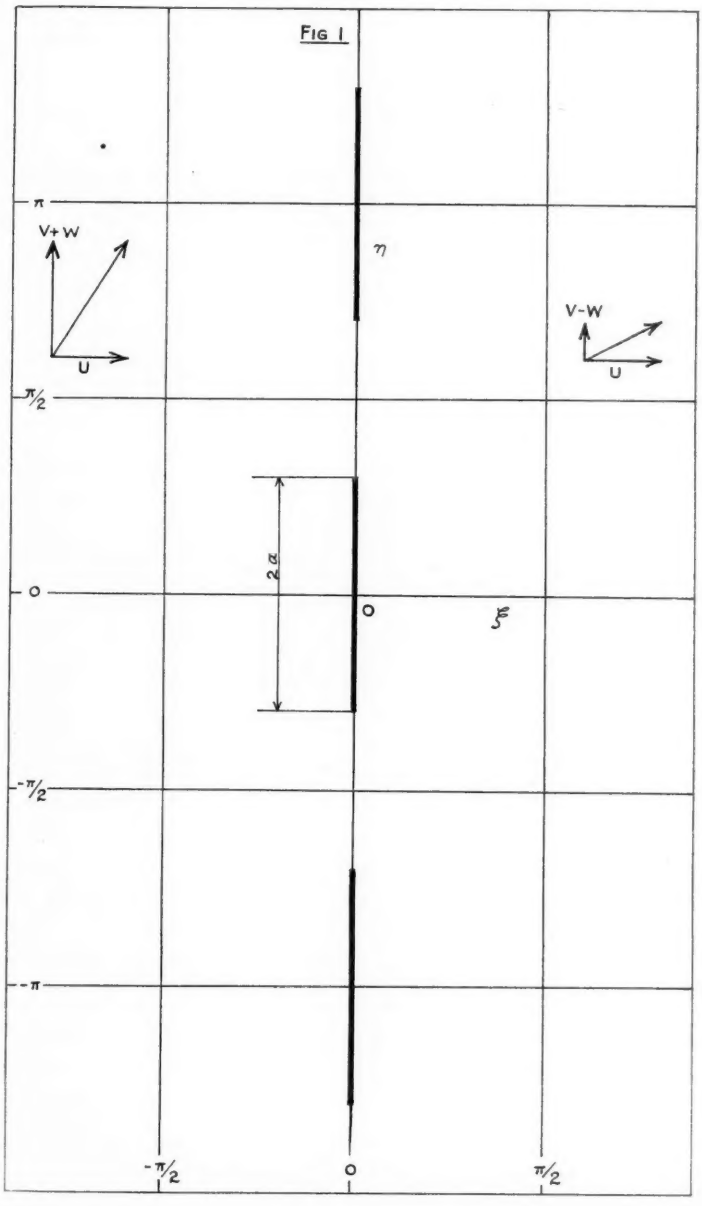


FIG 1
π
V+W
U
η
V-W
U
π/2
2α
0
0
ξ
-π/2
-π
-π/2
0
π/2

infinity in the positive direction of ξ, and to circulation round each lamina giving rise at infinity to velocities $\pm W$ parallel to the η axis.

The magnitude of the circulation round each lamina is given by

$$K = 2\int_{-a}^{a} \frac{W \cos\eta \, d\eta}{\sqrt{(\sin^2 a - \sin^2 \eta)}}$$
$$= 2\pi W \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Equations equivalent to (1) have been given by Alexandrow (Ref. 1), who appears to attribute the result to Joukowski, and more recently by Merchant (Ref. 2). Lamb (Ref. 3) also gives the term involving U; he attributes it to Larmor. Equation (1) has also been given previously by the present writer (Ref. 4).

It is now apparent that if conformal transformations connecting the ζ-plane and the z-plane can be developed, which convert the grid of flat laminæ into cascades of aerofoils in the z-plane, the regions infinitely distant from the cascades being identical, then the flow through the z-plane cascades may be determined by application of the transformations to equation (1).

It is often the case that interest attaches mainly to the direction of flow at large distances in front of and behind a cascade. When this is so it is not necessary to determine the actual flow through the cascade; equation (1) may be used instead, since the regions at infinite distances from the cascades are identical in the ζ and z-planes. For example, if the z-plane cascade has sharp trailing edges, the Kutta-Joukowski condition implies (in general) that the points in the ζ-plane which correspond to these trailing edges must be stagnation points. From equation (1) therefore a relation is obtained connecting U, V and W, which results in a single equation connecting the directions of inflow to and outflow from the cascade (see § 18). If in addition the z-plane cascade has sharp leading edges, and the condition is imposed that the flow shall have finite velocity at both the leading and trailing edges, then (1) yields two relations between U, V and W, which define unique values of the directions of inflow and outflow.

We shall now proceed to develop a transformation which converts the ζ-plane grid of laminæ into a wide range of cascades of aerofoils.

§ 2. Transformation of a Circle into a Flat Plate.

As a preliminary step, we shall consider the well-known transformation which converts isolated circles into flat plates and circular arcs. It will be convenient to introduce a third plane, the l-plane, where $l = m + in$.

Consider the transformation

$$z = l + \frac{a^2 e^{2i\sigma}}{4\,l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

When l becomes indefinitely large, z becomes equal to l; the regions at infinity are therefore identical. Equation (7) may be written in the alternative forms

$$l\frac{(z-l)}{e^{2i\sigma}} = \frac{a^2}{4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and

$$2\,l = z + \sqrt{(z^2 - a^2 e^{2i\sigma})} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where the positive sign is used for the radical in (9) to ensure that the regions at infinity are the same. Apply (7) to the l-plane circle

$$2\,l = a e^{i\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Then

$$2\,z = a e^{i\theta} + a e^{i\,(2\sigma - \theta)},$$

or

$$z = a e^{i\sigma} \cos(\theta - \sigma) \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Hence

$$x = a \cos(\theta - \sigma) \cos\sigma,$$
$$y = a \cos(\theta - \sigma) \sin\sigma,$$

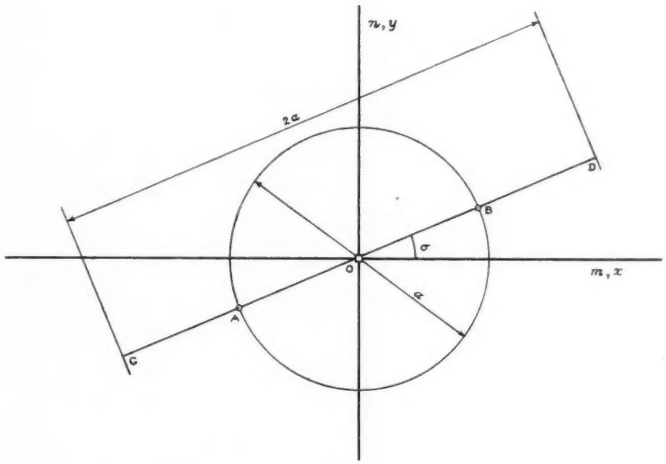
and the transform is accordingly that part of the straight line $y = x \tan \sigma$ lying between the points defined by $\cos(\theta - \sigma) = \pm 1$; it is thus a flat lamina of length $2a$, inclined at σ to the x axis, and having its centre at the origin. Fig. 2 shows the l-plane circle (10) and its z-plane transform (11); the co-ordinate axes are common to both planes.

By differentiation of (7),

$$\frac{dz}{dl} = 1 - \frac{a^2 e^{2i\sigma}}{4 l^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The infinities of (12) are at $l = 0$, *i.e.*, at the centre of the l-plane circle. The zeros of (12) are given by $2l = \pm a e^{i\sigma}$, which by (10) are the points on the l-plane circle defined by $\theta = \sigma$, $\theta = \pi + \sigma$. These points give $\cos(\theta - \sigma) = \pm 1$, and, as would be expected, thus correspond to the ends of the z-plane lamina. Fig. 2 shows the l-plane zeros at A and B; they are indicated by small circles. The infinities, indicated by a small square, are at O. The z-plane zeros are at C and D, the ends of the flat lamina.

FIG. 2.



There are thus no singularities in the regions of the z and l-planes external to the circle and lamina.

§3. Transformation of a Circle into a Flat Plate Round which the Flow is Known.

As a particular case of §2, put $\sigma = \pi/2$, and write ζ for z. Then the transformation becomes

$$\zeta = l - \frac{a^2}{4l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

or

$$l(l - \zeta) = \frac{a^2}{4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

or

$$2l = \zeta + \sqrt{(\zeta^2 + a^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

In this case, the transform of the l-plane circle is the flat lamina lying along the η axis between the points $\zeta = \pm ia$.

Now equation (1) can be used to obtain the flow round an isolated flat plate. Let a become indefinitely small in (1), and consider only that part of the ζ-plane which surrounds a lamina and which is also so small that it can be considered to be uninfluenced by the other small laminæ. Then (1) reduces to

$$\frac{dw}{d\zeta} = \frac{U\zeta + iW}{\sqrt{(a^2+\zeta^2)}} - iV \quad . \quad . \quad . \quad . \quad . \quad (16)$$

The flow round the l-plane circle (10) is defined by

$$\frac{dw}{dl} = \frac{dw}{d\zeta}\frac{d\zeta}{dl}$$

and in view of (6), (13) and (16), this reduces to

$$\frac{dw}{dl} = U\left(1 - \frac{a^2}{4l^2}\right) - iV\left(1 + \frac{a^2}{4l^2}\right) + \frac{iK}{2\pi l} \quad . \quad . \quad . \quad (17)$$

which are the usual equations for flow, with circulation, past the circle.

§4. Transformation Connecting Two Flat Plates.

By elimination of l between the transformations of §§2 and 3 a direct connection is obtained between the ζ and z-planes. It is

$$2z = \zeta + \sqrt{(a^2+\zeta^2)} + \frac{a^2 e^{2i\sigma}}{\zeta + \sqrt{(a^2+\zeta^2)}}$$

which can be written

$$ze^{-i\sigma} = \sqrt{(\zeta^2+a^2)}\cos\sigma - i\zeta\sin\sigma \quad . \quad . \quad . \quad (18)$$

or

$$z + i(\zeta - z)\tan\sigma = \sqrt{(\zeta^2+a^2)} \quad . \quad . \quad . \quad . \quad (19)$$

Equation (18) shows that when ζ becomes infinitely large, z becomes identical with ζ. Moreover, the ζ-plane lamina $\zeta = ia\sin\theta$ transforms by (18) into the z-plane lamina (11).

Differentiation of (18) yields

$$e^{-i\sigma}\frac{dz}{d\zeta} = \frac{\zeta\cos\sigma}{\sqrt{(\zeta^2+a^2)}} - i\sin\sigma \quad . \quad . \quad . \quad . \quad (20)$$

The infinities of (20) are given by $\zeta = \pm ia$, and lie at the ends of the ζ-plane lamina. The zeros are given by $\zeta = \pm ia\sin\sigma$, which on substitution in (18) gives $z = \pm ae^{i\sigma}$, the ends of the z-plane lamina.

The transformation of this paragraph can be obtained directly in the following manner. In (16) let $W = 0$ and $V = U\tan\sigma$. Then (16) becomes

$$\frac{dw}{d\zeta} = U\left\{\frac{\zeta}{\sqrt{(a^2+\zeta^2)}} - i\tan\sigma\right\} \quad . \quad . \quad . \quad . \quad (21)$$

This represents the flow, without circulation, past the ζ-plane lamina, the direction of the flow at infinity making an angle σ with the real axis. Now suppose we apply such a transformation that the flow throughout the z-plane is uniform and rectilinear; it will be given by

$$\frac{dw}{dz} = U(1 - i\tan\sigma)$$

$$= Ue^{-i\sigma}\sec\sigma \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The transform of the ζ-plane lamina must obviously be a flat lamina lying along the streamlines in the z-plane, since these lines are all straight and parallel.

Elimination of w between (21) and (22) immediately gives equation (20); integration of this equation gives the transformation (18).

§5. Transformation of a Cascade of Ovals into a Cascade of Flat Plates.

The results of §§2 to 4 can be generalised to the case of a cascade. Consider the transformation

$$\tanh l\tanh\left(\frac{z-l}{e^{2ir}}\right) = \tan^2\frac{a}{2} \quad . \quad . \quad . \quad . \quad (23)$$

where $0 \leqslant a \leqslant \pi/2$. This is evidently a generalisation of equation (8), to which it reduces when l, z, and a are all small. Equation (23) is periodic along the imaginary axes; for if both z and l are increased by $ri\pi$, where r is any integer, the transformation is unchanged. Moreover, the regions of the z and l-planes infinitely distant from the imaginary axes are identical, for if (23) is written in the form

$$z = l + e^{2i\sigma} \tanh^{-1} (\coth l \tan^2 a/2) \quad . \quad . \quad . \quad (24)$$

and if the real part of l is made indefinitely large, $\coth l$ tends to unity, and (24) therefore reduces effectively to $z = l$.

Consider also the cascade of ovals

$$\tanh^2 m = \tan\left(\frac{a}{2} - n\right)\tan\left(\frac{a}{2} + n\right) \quad . \quad . \quad . \quad (25)$$

This equation may be written in the useful alternative forms

$$\cosh 2m = \sec a \cos 2n \quad . \quad . \quad . \quad . \quad (26)$$

$$\tanh l \tanh \bar{l} = \tan^2 a/2 \quad . \quad . \quad . \quad . \quad . \quad (27)$$

where $\bar{l}$ is the conjugate of l. If n is increased by any integral multiple of π, (25) is unchanged; the ovals therefore appear along the imaginary axis with a period of π, which is the same as that of the transformation (23). When l and a are small, (25) reduces to

$$m^2 + n^2 = a^2/4,$$

which is the l-plane circle (10). Fig. 3 shows a number of ovals corresponding to $a = \pi/12$, $\pi/6$, $\pi/4$, $\pi/3$, $5\pi/12$, $\pi/2$. It will be seen that up to $a = \pi/4$, the ovals are not very different from circles. Above this value of a the elongation of the ovals becomes more pronounced, until for $a = \pi/2$ they degenerate into a cascade of parallel straight lines. The ovals strongly resemble ellipses; and the minor axis of each oval is of length a in every case. It should be remembered that each oval repeats at intervals of π along the n axis.

Equations (23) and (27) show that when the transformation is applied to the cascade of ovals,

$$\frac{z - l}{e^{2i\sigma}} = \bar{l} + ri\pi \quad . \quad . \quad . \quad . \quad . \quad (28)$$

which may be reduced to

$$z - ri\pi = 2 e^{i\sigma} \{ m \cos \sigma + (n - r\pi) \sin \sigma \} \quad . \quad . \quad . \quad (29)$$

or

$$x = 2 \{ m \cos \sigma + (n - r\pi) \sin \sigma \} \cos \sigma,$$

$$y - r\pi = 2 \{ m \cos \sigma + (n - r\pi) \sin \sigma \} \sin \sigma.$$

The transforms of the ovals are thus those parts of the family of parallel straight lines $y = r\pi + x \tan \sigma$ which lie between the points defined by the extreme values assumed by the function

$$m \cos \sigma + (n - r\pi) \sin \sigma \quad . \quad . \quad . \quad . \quad (30)$$

as the point l travels round the ovals. Fig. 4 shows three members of the cascade of ovals defined by $a = 5\pi/12$, together with the flat laminæ into which they transform when $\sigma = \pi/6$. It should be compared with Fig. 2.

The quantity $n - r\pi$ which appears in (29) and (30) has of course precisely the same value for points in the same relative positions on each oval. It will be convenient in what follows to omit the multiples of π which should strictly be added to the imaginary co-ordinates; it is evident that no loss of generality is involved.

Differentiation of equation (24) yields

$$\frac{dz}{dl} = 1 - \frac{e^{2i\sigma} \tan^2 a/2}{\sinh^2 l - \cosh^2 l \tan^4 a/2} \quad . \quad . \quad . \quad . \quad (31)$$

the infinities of which are given by

$$\tanh^2 l = \tan^4 a/2$$

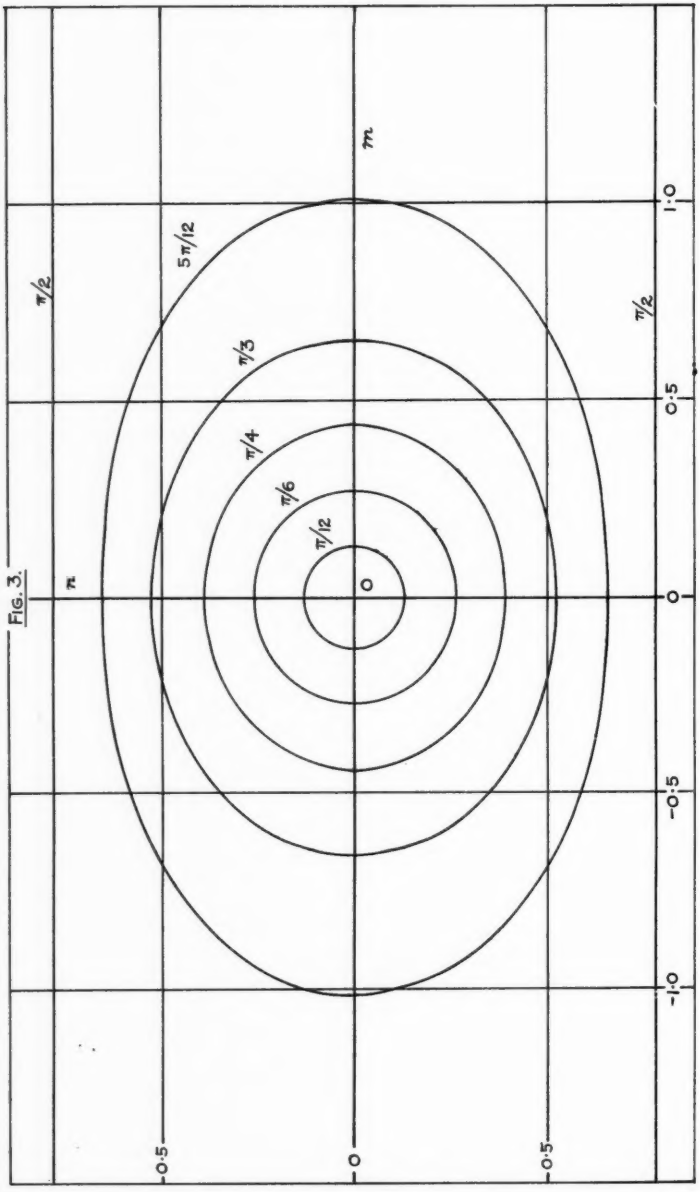


FIG. 3.
π
π/2
5π/12
π/3
π/4
π/6
π/12
0
π
π/2
0
1·0
0·5
-0·5
-1·0
0·5
0
0·5

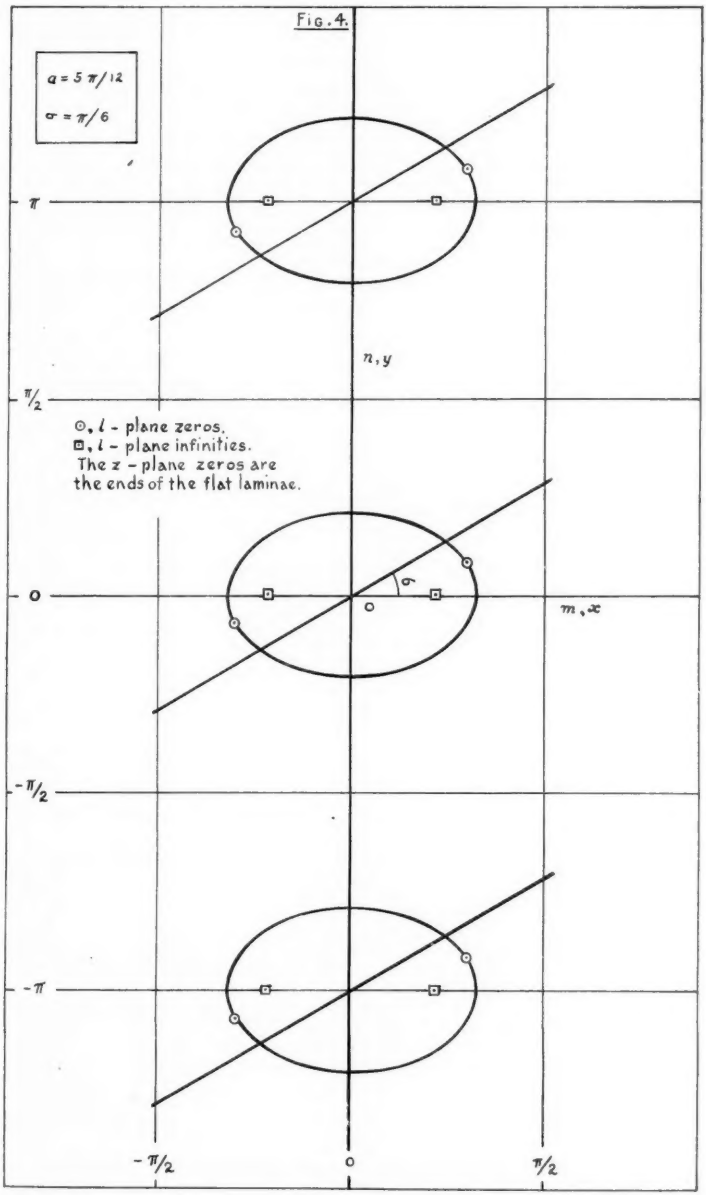


Fig. 4.
$\alpha = 5\pi/12$
$\sigma = \pi/6$
π
$\pi/2$
n, y
⊙, ζ - plane zeros.
⊡, ζ - plane infinities.
The z - plane zeros are
the ends of the flat laminae.
0
α
0
m, x
$-\pi/2$
$-\pi$
$-\pi/2$
0
$\pi/2$

or

$$\left.\begin{aligned} \tanh m &= \pm \tan^2 a/2 \\ n &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (32)$$

By (25), the intercepts of the oval on the real axis are given by

$$\tanh m = \pm \tan a/2.$$

Hence, since $0 \leqslant a \leqslant \pi/2$, the singularities defined by (32) lie inside the oval. The zeros of (31) are given by

$$\sinh^2 l - \cosh^2 l \tan^4 a/2 - e^{2i\sigma} \tan^2 a/2 = 0$$

which can be written in the form

$$\tanh^2 l \,(1 + e^{2i\sigma} \tan^2 a/2) = \tan^2 a/2 \,(e^{2i\sigma} + \tan^2 a/2) \quad . \quad . \quad (33)$$

The points thus defined lie on the oval; for the equation conjugate to (33) is

$$\tanh^2 \bar{l} \,(1 + e^{-2i\sigma} \tan^2 a/2) = \tan^2 a/2 \,(e^{-2i\sigma} + \tan^2 a/2) \quad . \quad . \quad (34)$$

and multiplication of (33) and (34) together gives the equation of the oval in the form (27). It is thus possible to regard (33) as a definition of the oval, in which σ is an independent variable.

The points defined by (33) must of course correspond to the ends of the z-plane laminæ (29). To prove this, we may note that the ends of the z-plane lamina, which correspond to the extreme values of the function (30), must therefore be defined by

$$\frac{dm}{dn} = -\tan \sigma \quad . \quad . \quad . \quad . \quad . \quad (35)$$

Differentiation of equation (26) and substitution from (35) gives the co-ordinates of the points on the oval which correspond to the ends of the z-plane lamina in the convenient form

$$\left.\begin{aligned} \sinh 2m &= \pm \tan a \cos \sigma \\ \sin 2n &= \pm \sin a \sin \sigma \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (36)$$

where corresponding signs are to be taken together. The equations in (36) can be combined together to give

$$\cos a \cosh 2l = 1 - \sin^2 a \sin^2 \sigma + i \sin^2 a \sin \sigma \cos \sigma$$

and by writing

$$\cosh 2l = \frac{1 + \tanh^2 l}{1 - \tanh^2 l}$$

equation (33) may be derived. Hence the l-plane zeros correspond to the ends of the z-plane laminæ. Fig. 4 shows the positions of the l-plane singularities in a manner corresponding to that of Fig. 2.

By (29) and (36), the z-plane co-ordinates of the ends of the laminæ, omitting multiples of π, are

$$\left.\begin{aligned} x &= \pm \tfrac{1}{2} c \cos \sigma \\ y &= \pm \tfrac{1}{2} c \sin \sigma \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (37)$$

where

$$c = 2 \{ \cos \sigma \sinh^{-1} (\tan a \cos \sigma) + \sin \sigma \sin^{-1} (\sin a \sin \sigma) \} \quad . \quad (38)$$

is the chord of the laminæ. The gap-chord ratio of the cascade is π/c.

§6.—Transformation of the Cascade of Ovals into the Grid through which the Flow is known. Flow Past the Ovals.

As in §3, we now put $\sigma = \pi/2$ and write ζ for z. The transformation (23) then assumes the form

$$\tanh l \tanh (l - \zeta) = \tan^2 a/2 \quad . \quad . \quad . \quad . \quad (39)$$

This equation is the generalisation of (14). By (29), the transform of the l-plane oval (25) is now

$$\left.\begin{aligned} \xi &= 0 \\ \eta &= 2n \end{aligned}\right\}. \quad . \quad . \quad . \quad . \quad . \quad (40)$$

By (37) and (38), the ends of the lamina (40) are the points on the η axis given by

$$\eta = \pm a \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

Equation (39) therefore connects the cascade of l-plane ovals (25) with the grid of flat laminæ discussed in §1, the flow through which is defined by equation (1). The general flow past the ovals is therefore determinable by elimination of ζ between (39) and (1); the result may be written

$$\left(\frac{\tanh^2 l - \tan^2 a/2}{1 - \tan^2 a/2}\right)\frac{dw}{dl} = U\left(\frac{\tanh^2 l - \tan^2 a/2}{1 - \tan^2 a/2}\right) - iV\left(\frac{\tanh^2 l + \tan^2 a/2}{1 + \tan^2 a/2}\right) + iW \tanh l \quad . \quad . \quad . \quad . \quad (42)$$

When a and l are small, this reduces to the flow past a circle given by equation (17).

§7. Transformation Connecting the Grid and the Cascade of Inclined Flat Plates.

As in §4 we may obtain a direct connection between the ζ and z-planes by elimination of l between (23) and (39). Comparison of these two equations yields the result (omitting multiples of $i\pi$)

$$z - l = e^{2i\sigma}(l - \zeta) \quad . \quad . \quad . \quad . \quad . \quad (43)$$

or

$$2l = \zeta + z + i(\zeta - z)\tan\sigma \quad . \quad . \quad . \quad . \quad (44)$$

Now equation (39) may be written in the form

$$\cosh(2l - \zeta) = \sec a \cosh\zeta \quad . \quad . \quad . \quad . \quad (45)$$

and substitution for l from (44) in (45) yields

$$\cosh\{z + i(\zeta - z)\tan\sigma\} = \sec a \cosh\zeta \quad . \quad . \quad . \quad (46)$$

This equation is the generalisation of (19), to which it reduces when z, ζ, and a are small. It may be written alternatively as

$$ze^{-i\sigma} = \cos\sigma \cosh^{-1}(\sec a \cosh\zeta) - i\zeta\sin\sigma \quad . \quad . \quad (47)$$

The ζ-plane lamina lying between the points $\zeta = \pm ia$ is defined by $\zeta = i\eta$ with $\sec a \cos\eta > 1$; the transform in the z-plane is therefore, by (47)

$$ze^{-i\sigma} = \cos\sigma \cosh^{-1}(\sec a \cos\eta) + \eta\sin\sigma \quad . \quad . \quad . \quad (48)$$

This equation is identical with (29), since equations (26) and (40) give

$$2n = \eta$$
$$2m = \cosh^{-1}(\sec a \cos 2n)$$
$$= \cosh^{-1}(\sec a \cos\eta).$$

Differentiation of (47) yields

$$e^{-i\sigma}\frac{dz}{d\zeta} = \frac{\sinh\zeta\cos\sigma}{\sqrt{(\sinh^2\zeta + \sin^2 a)}} - i\sin\sigma \quad . \quad . \quad . \quad (49)$$

an equation which compares with (20). It has infinities for $\zeta = \pm ia$, that is, at the ends of the ζ-plane lamina; and the zeros are given by

$$\sinh^2\zeta + \sin^2 a \sin^2\sigma = 0,$$

or

$$\left.\begin{aligned}\xi &= 0\\ \eta &= \sin^{-1}(\sin a \sin\sigma)\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (50)$$

The corresponding points in the z-plane are given by (48). Now, when η is defined by (50)

$$\cosh^{-1}(\sec a \cos\eta) = \sinh^{-1}(\tan a \cos\sigma),$$

and the z-plane co-ordinates of the zeros are therefore given by equations (37) and (38), which define the ends of the laminæ.

As in the case of the isolated plate, the transformation (47) may be derived from consideration of the fluid flow discussed in §1. Put $W = 0$ and write $V = U\tan\sigma$; then equation (1) becomes

$$\frac{dw}{d\zeta} = U\left\{\frac{\sinh\zeta}{\sqrt{(\sin^2\alpha+\sinh^2\zeta)}} - i\tan\sigma\right\} \quad . \quad . \quad . \quad (51)$$

Also, let the flow in the z-plane be uniform and rectilinear, so that

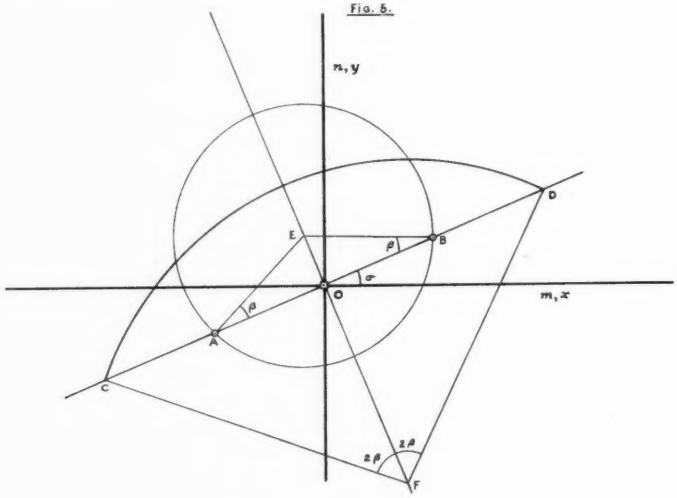
$$\frac{dw}{dz} = U\ (1 - i\tan\sigma) \quad . \quad . \quad . \quad . \quad . \quad (52)$$

Elimination of w between (51) and (52) gives equation (49), which on integration gives the transformation (45).

§8. Transformation of a Circle into a Circular Arc.

So far, we have shown how a circle may be transformed into an inclined flat plate, and have given the equations determining the flow round the circle. This has been generalised to give the transformation of a cascade of ovals into a cascade of inclined flat plates; the flow past the ovals has been derived, so that the flow past the inclined flat plates can be obtained. To proceed to the case of a cascade of curved bodies, we shall first consider the transformation of an isolated circle into a circular arc, and shall then generalise this by methods parallel to those of the previous discussion.

Fig. 5.



The results of §2 may readily be adapted to the case of a single circular arc. It has been shown that the transformation (7) has two singularities (zeros) at the points defined by $2l = \pm ae^{i\sigma}$, and two infinities at $l = 0$. In §2 the transformation is applied to a circle passing through the zeros and with its centre at the origin (see Fig. 2). Now consider a circle passing through the zeros but having its centre offset from the origin; the infinities at the origin will still lie inside the circle (see Fig. 5).

In the first place, it is evident that the transform of the circle in the z-plane will have zero thickness. For any one point z defines two points in the l-plane which are given by

$$l^2 - lz + \frac{a^2e^{2i\sigma}}{4} = 0 \quad . \quad . \quad . \quad . \quad . \quad (53)$$

a quadratic obtained from (7). Also the two zeros are given by

$$l^2 - \frac{a^2e^{2i\sigma}}{4} = 0 \quad . \quad . \quad . \quad . \quad . \quad (54)$$

By the properties of invariants of binary forms (see for instance Grace and Young (Ref. 5)) it follows that the four points defined by (53) and (54) are harmonically concyclic. Conversely, if any circle is taken through the two zeros, then two harmonically related points on the circle transform into the same point in the z-plane. It follows that the two arcs into which the zeros divide the l-plane circle each transform into the same thin lamina in the z-plane.

Suppose the l-plane circle to be of radius $\frac{1}{2}b$ and to pass through the two zeros. It will be convenient to write $b = a \sec \beta$, where β is the angle between the line joining the zeros together and the line joining either zero to the centre of the circle. The equation of the circle will then be

$$2l = ae^{i\theta} \sec \beta + iae^{i\sigma} \tan \beta \quad . \quad . \quad . \quad . \quad (55)$$

Substitution of the values of the zeros in (55) gives the equation

$$\pm e^{i\sigma} = e^{i\theta} \sec \beta + ie^{i\sigma} \tan \beta,$$

whence the values of θ corresponding to the zeros are

$$\left.\begin{aligned} \theta &= \sigma - \beta \\ \theta &= \pi + \sigma + \beta \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (56)$$

a result which is also obvious from Fig. 5. Application of the transformation (7) to the circle (55) gives

$$2z = ae^{i\theta} \sec \beta + iae^{i\sigma} \tan \beta + \frac{a^2 e^{2i\sigma}}{ae^{i\sigma} \sec \beta + iae^{i\sigma} \tan \beta}$$

which may readily be reduced to

$$ze^{-i\sigma} \sin 2\beta = ae^{i(\theta-\sigma)} \left\{ \frac{e^{i(\theta-\sigma)} \sin \beta + i}{e^{i(\theta-\sigma)} + i \sin \beta} \right\} - ia \cos 2\beta \quad . \quad . \quad (57)$$

Now the moduli of the numerator and denominator of the expression in braces are equal; it is therefore legitimate to write the quotient as $e^{i\alpha}$, where

$$\sin \alpha = \frac{\cos(\theta-\sigma) \cos^2 \beta}{1 + 2 \sin(\theta-\sigma) \sin \beta + \sin^2 \beta} \quad . \quad . \quad . \quad (58)$$

Accordingly, equation (57) reduces to

$$z = ae^{i(\theta+\alpha)} \operatorname{cosec} 2\beta - iae^{i\sigma} \cot 2\beta \quad . \quad . \quad . \quad (59)$$

Since α is a function of θ, the point z defined by (59) moves on the circle of radius $a \operatorname{cosec} 2\beta$ which has its centre at the point $z = -iae^{i\sigma} \cot 2\beta$. The range of variation of $\theta + \alpha$ is however limited; and therefore (59) represents a circular arc. The function

$$\theta + \alpha = \theta + \sin^{-1} \left\{ \frac{\cos(\theta-\sigma) \cos^2 \beta}{1 + 2 \sin(\theta-\sigma) \sin \beta + \sin^2 \beta} \right\}$$

is stationary with respect to θ when

$$\sin(\theta-\sigma) = -\sin \beta \quad . \quad . \quad . \quad . \quad . \quad (60)$$

which yields the values of θ given by (56) and therefore corresponds to the zeros of the transformation. The corresponding values of $\theta + \alpha$ are then found to be $\pi/2 + \sigma \pm 2\beta$. The circular arc thus subtends 4β at its centre, and the line of symmetry is inclined at $\pi/2 + \sigma$ to the x axis. In view of the co-ordinates of the centre, this line of symmetry passes through the origin. These results are illustrated by Fig. 5. The co-ordinate axes are common to both the z and l-planes. The infinities of the transformation are at the origin. A and B are the zeros in the l-plane; C and D are the corresponding points in the z-plane. A circle is drawn with centre E and passing through A and B; its radius is $\frac{1}{2}b$, or $\frac{1}{2}a \sec \beta$, where $OA = OB = \frac{1}{2}a$. In the z-plane, the transform of this circle is the circular arc joining C and D and having its centre at F.

Since the ends of the circular arc coincide with the zeros of the transformation, all the circular arcs defined by different values of the parameter b have a common chord line, which coincides with the flat lamina of §2 and Fig. 2.

An instructive alternative way of obtaining the co-ordinates of the ends of the circular arc is as follows. Any point on the circular arc has the co-ordinates

$$x = a \operatorname{cosec} 2\beta \{ \cos(\theta+\alpha) + \cos 2\beta \sin\sigma \}$$
$$y = a \operatorname{cosec} 2\beta \{ \sin(\theta+\alpha) - \cos 2\beta \cos\sigma \} .$$

Substitution of these values in the equation

$$d = y\cos\sigma - x\sin\sigma$$

gives the distance d of the point from the line $y = x\tan\sigma$. The result is

$$d = \frac{a\tan\beta \{ \sin(\theta-\sigma) + \sin\beta \}^2}{\cos^2(\theta-\sigma) + \{ \sin(\theta-\sigma) + \sin\beta \}^2}$$

Since this is always one-signed, the circular arc lies entirely on one side of the line $y = x\tan\sigma$, and its ends touch the line when

$$\sin(\theta-\sigma) + \sin\beta = 0,$$

which agrees with (60).

§9. The Process of Transformation of a Cascade of Ovals into a Cascade of Curved Bodies.

The process of obtaining a circular arc lamina in the z-plane from a circle in the l-plane can be regarded in the following light. In the l-plane, plot the zeros of the transformation (7), and draw the straight line joining them. The origin bisects this line. Now draw the circle on this line as diameter; then, as in Fig. 2, application of the transformation (7) to this circle gives a flat lamina in the z-plane. Next draw another circle concentric with the first but of larger radius $\frac{1}{2}b$, and then displace this circle at right angles to the line joining the zeros until the zeros lie on its circumference. Application of the transformation (7) to the circle in this position then yields, as in Fig. 5, a circular arc in the z-plane.

A precisely similar process can be used to generate cascades of curved figures in the z-plane. Equation (25) defines a family of ovals each of which corresponds to a particular value of the parameter a. Fix on a given value of a; then application of the transformation (23) to the corresponding cascade produces in the z-plane a cascade of flat laminæ, as in Fig. 4. Now consider another cascade of the family, for which the parameter assumes the value b where $b > a$; each oval of this cascade will enclose two of the zeros of (23) within its circumference. It is evidently possible to displace the whole of the cascade of ovals, keeping the axis of the cascade parallel to the imaginary axis, in such a manner that the two zeros enclosed by each oval come to the circumference of the oval. Application of the transformation (23) to the cascade in this position will then give rise in the z-plane to a cascade of curved figures, the ends of which are sharp and coincide with the ends of the flat laminæ derived in the simple case.

§10. The Positions of the Singularities of the Transformation in Relation to the Ovals of a Displaced Cascade.

The equation of the displaced ovals may be found as follows. The transformation (23) has zeros at the points defined by (36), that is,

$$\left.\begin{aligned} \sinh 2m &= \pm\tan a\cos\sigma \\ \sin 2n &= \pm\sin a\sin\sigma \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (61)$$

where corresponding signs are to be taken together. The equation of an oval in its undisplaced position, with its centre at the origin, is

$$\cosh 2m = \sec b\cos 2n \quad . \quad . \quad . \quad . \quad (62)$$

where $b > a$. If this oval is displaced so that its centre is brought to the point (μ, ν) its equation will be

$$\cosh(2m - 2\mu) = \sec b\cos(2n - 2\nu) \quad . \quad . \quad . \quad (63)$$

and expansion of (63) and substitution of the two points (61) yields two equations for μ and v the solutions of which are

$$\left.\begin{aligned}\sin 2v &= \pm \sec a \cos\sigma \sqrt{(\cos^2 a - \cos^2 b)} \\ -\sinh 2\mu &= \pm \sec b \sin\sigma \sqrt{(\cos^2 a - \cos^2 b)}\end{aligned}\right\} \quad . \quad . \quad (64)$$

where corresponding signs are to be taken together. The alternative signs show that the displacement may be in opposite directions; it will be convenient to use only the positive sign in what follows. When a and b are small, and $b = a \sec\beta$, equation (64) yields

$$\mu + iv = iae^{i\sigma} \tan\beta,$$

which is the centre of the circle (55).

It will now be shown that the remaining singularities of the transformation, namely, the infinities, always lie inside the displaced oval. The intercepts of the displaced oval on the real axis $n=0$ are the points $(m_1, 0)$ where, by (63)

$$\cosh(2m_1 - 2\mu) = \sec b \cos 2v \quad . \quad . \quad . \quad (65)$$

If (64) is used to eliminate v from (65), the solution for m_1 may be written in the form

$$\cos a \cosh 2m_1 = 1 + \sinh^2 2\mu \pm \sqrt{\{(\tfrac{1}{2}\sin^2 a + \sinh^2 2\mu)^2 - (\tfrac{1}{2}\sin^2 a)^2\}} \quad (66)$$

Also, the co-ordinates of the infinities are $(m_2, 0)$, where by (32)

$$\tanh m_2 = \pm \tan^2 a/2,$$

which may also be written as

$$\cos a \cosh 2m_2 = 1 - \tfrac{1}{2}\sin^2 a \quad . \quad . \quad . \quad . \quad (67)$$

Subtraction of (67) from (66) gives

$$\cos a (\cosh 2m_1 - \cosh 2m_2)$$
$$= \tfrac{1}{2}\sin^2 a + \sinh^2 2\mu \pm \sqrt{\{(\tfrac{1}{2}\sin^2 a + \sinh^2 2\mu)^2 - (\tfrac{1}{2}\sin^2 a)^2\}} \quad . \quad (68)$$

The right-hand side of (68) is evidently always positive; hence

$$\cosh 2m_1 > \cosh 2m_2,$$

and therefore the infinities lie inside the oval.

§11. Numerical and Graphical Methods for the Practical Problem.

Formally, the position of any point in the z-plane is given explicitly in terms of the corresponding point in the l-plane by equation (24). In practice it is necessary for computational purposes to separate the real and imaginary parts of the equation.* The following formulæ and methods have been found useful in the examples given later.

Equation (23) may be written

$$\tanh(m + in)\tanh(A + iB) = \tan^2 a/2,$$

where

$$A + iB = \frac{z - l}{e^{2i\sigma}} \quad . \quad . \quad . \quad . \quad . \quad (69)$$

Hence it may be shown that, for given values of m and n, A and B are defined by the equations

$$\tanh 2A = \frac{\sin^2 a \sinh 2m}{(1 + \cos^2 a)\cosh 2m - 2\cos a \cos 2n}$$

$$\tan 2B = \frac{\sin^2 a \sin 2n}{(1 + \cos^2 a)\cos 2n - 2\cos a \cosh 2m}$$

If the first of these equations is used to find A, B may usually be found more simply from the relation

$$\sin 2B \sinh 2m + \sinh 2A \sin 2n = 0.$$

* Jahnke u. Emde (Funktionentafeln) give a few values of the hyperbolic functions of a complex argument, but the intervals are too large for the present purpose.

Care must be taken to ensure that the supplement of $2B$ is not derived from this equation instead of $2B$ itself. This ambiguity may be avoided by use of the graphical solution outlined below.

When A and B have been found, (69) shows that the z-plane co-ordinates corresponding to the given values of m and n are

$$\left.\begin{aligned} x &= m + A\cos 2\sigma - B\sin 2\sigma \\ y &= n + A\sin 2\sigma + B\cos 2\sigma \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (70)$$

In the numerical application of these formulæ, the Smithsonian tables of hyperbolic functions or Milne-Thomson and Comrie's four-figure mathematical tables are of great utility.

When considerable accuracy is not required, the following graphical method of solution may be used. Let

$$\tanh(m+in) = p+iq.$$

Then for a fixed value of m, the locus of the point (p, q) as n varies is the circle

$$(p-\coth 2m)^2 + q^2 = \operatorname{cosech}^2 2m.$$

Similarly, for a fixed value of n, the locus of (p, q) as m varies is the circle

$$p^2 + (q+\cot 2n)^2 = \operatorname{cosec}^2 2n.$$

The families of circles so defined form a mutually orthogonal coaxal system, part of which is shown in Fig. 6. In this figure, the circles are for convenience drawn for values of m and n which are integral multiples of $\pi/20$. From its equation it is evident that the circle corresponding to any given value of n coincides with the circle corresponding to $n-\pi/2$. Hence, since one intersection of this circle with the orthogonal circle defined by a given value of m has co-ordinates corresponding to $\tanh(m+in)$, the other intersection of the two circles will correspond to $\coth(m+in)$.

Now (23) may be written

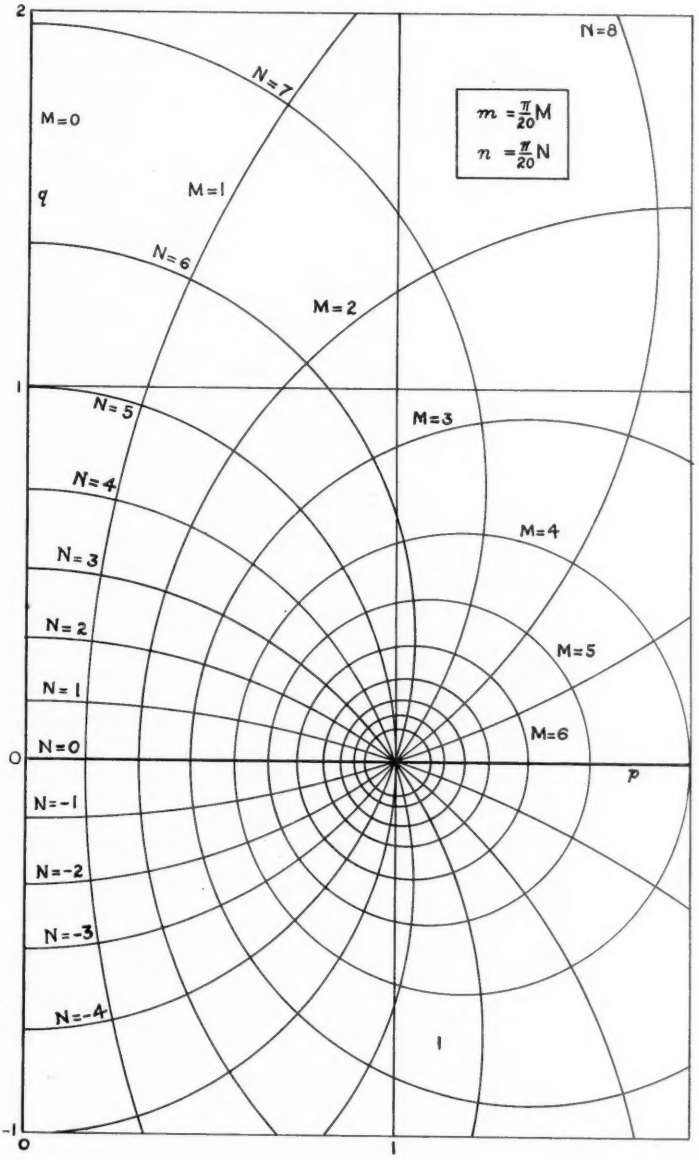
$$\tanh(A+iB) = \coth(m+in)\tan^2 a/2.$$

Accordingly, if the values of m and n are given, Fig. 6 may be used to read off $\coth(m+in)$. Both the co-ordinates thus found are next reduced in the ratio $\tan^2 a/2$, and the resulting point is used in the reverse manner (by regarding the orthogonal system of circles as curvilinear co-ordinates) to read off from Fig. 6 the required values of A and B. Equation (70) is then used to find x and y.

In this manner, any z-plane curve corresponding to any given l-plane curve is readily found; in particular the transforms of the cascades of ovals may be obtained. It is sometimes convenient, especially when the transformation (23), with a and σ fixed, is to be applied to several l-plane figures, to find the z-plane curves corresponding to the usual orthogonal Cartesian network which divides the l-plane into small squares. The curves in the z-plane form a corresponding orthogonal system of curvilinear squares. The particular case defined by $a=1.1$, $\sigma=\pi/6$, is shown in Figs. 7 and 8. Fig. 7 shows the part of the l-plane bounded by the lines $m=-\pi/2$, $m=+\pi/2$, $n=0$, and $n=\pi/2$; it is subdivided into small squares of side $\pi/20$. The corresponding z-plane curves are shown in Fig. 8. The lines corresponding to constant values of n are shown broken to distinguish them from those defined by constant values of m. A particular curve in the l-plane is shown chain-dotted in Fig. 7, and the corresponding curve in the z-plane is similarly shown in Fig. 8; it was obtained by noting the points in which the l-plane curve cuts the Cartesian network in Fig. 7 and by marking the corresponding points in the curvilinear network of Fig. 8.

Now if the signs of m and n are changed, the signs of x and y are also changed; hence the curvilinear network corresponding to the portion of the l-plane bounded by $m=-\pi/2$, $m=+\pi/2$, $n=-\pi/2$ and $n=0$ is obtained by reflection of the network of Fig. 8 in both axes. In practice, it was found best to draw the l-plane figures on tracing paper, marking the axes, this paper being placed on Fig. 7; another sheet of tracing paper was placed over Fig. 8. The part of the z-plane curve corresponding to the part of the l-plane curve for which

Fig. 6


2
1
0
-1
0
1
q
p
N=8
N=7
N=6
N=5
N=4
N=3
N=2
N=1
N=0
N=-1
N=-2
N=-3
N=-4
M=0
M=1
M=2
M=3
M=4
M=5
M=6
$m = \frac{\pi}{20}M$
$n = \frac{\pi}{20}N$

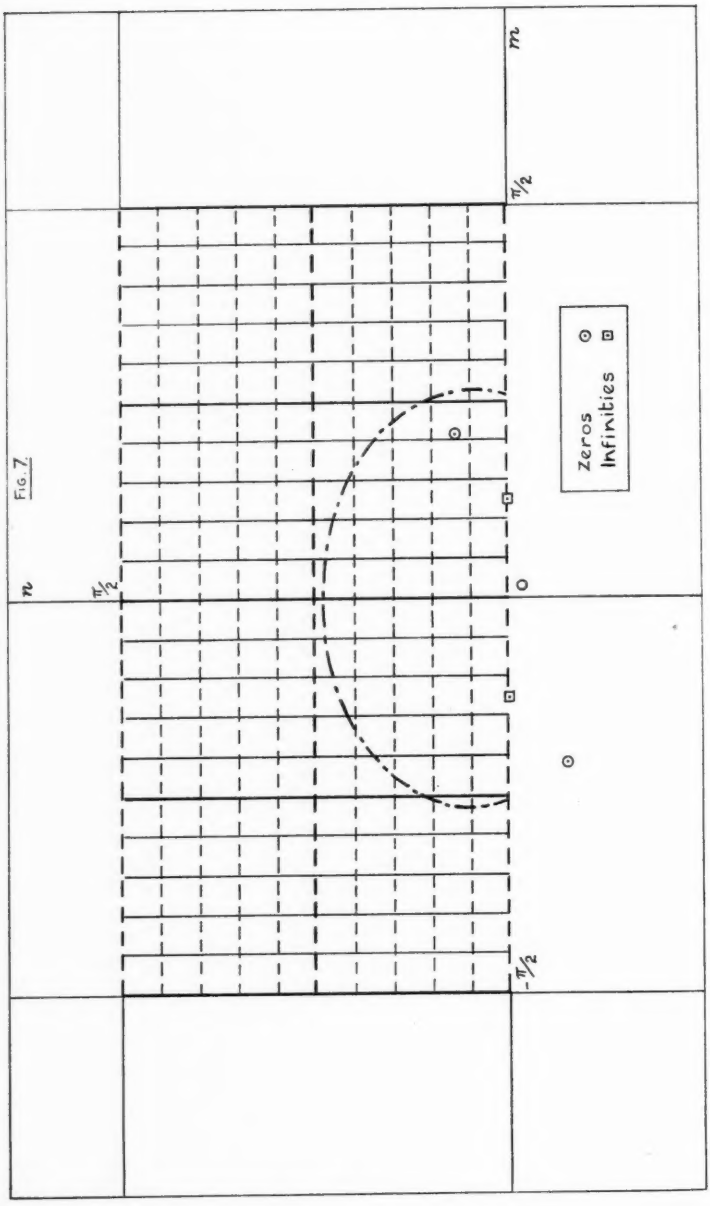


Fig. 7

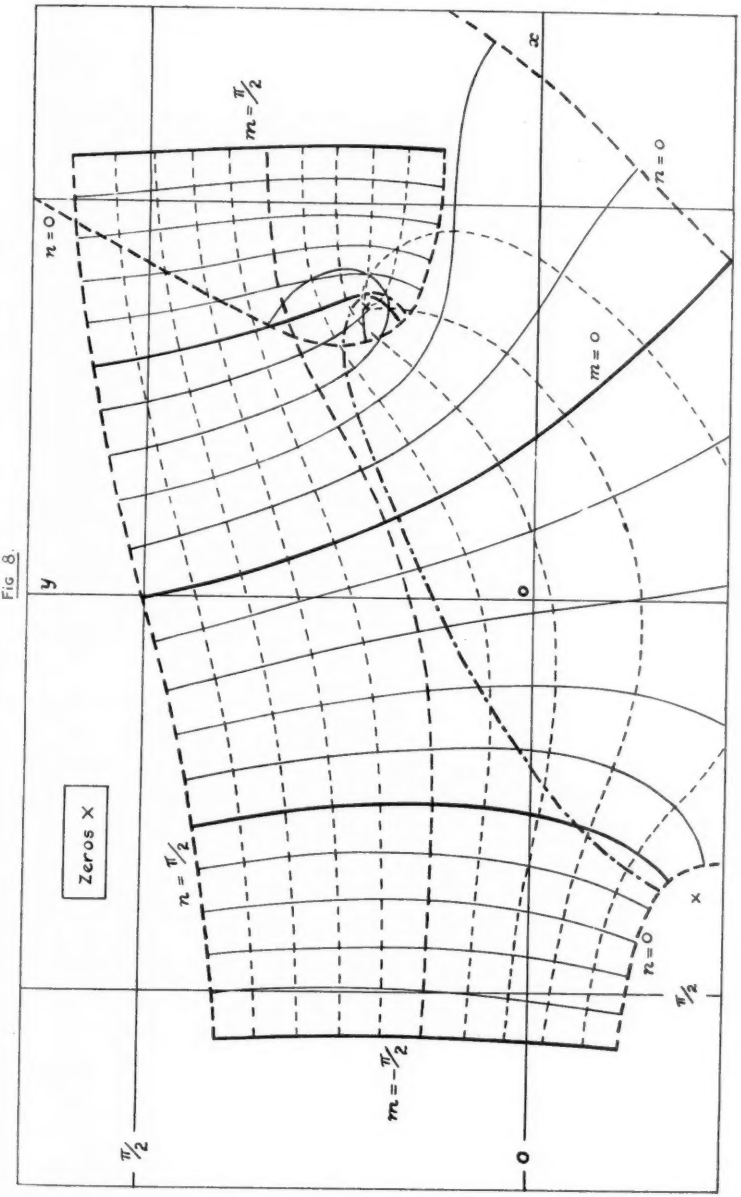


FIG. 8.

$n > 0$ was thus obtained. Both sheets of tracing paper were then rotated about the origin through π, when the remaining part of the z-plane curve, corresponding to $n < 0$, was obtained.

It will be seen that the z-plane network overlaps itself in places; also the points corresponding to the infinities are at infinity. However, provided the l-plane figures to be transformed enclose all the singularities within their circumferences, no difficulty is experienced in deriving the z-plane curves.

§12. Transform of a Displaced Oval Passing Through Two Singularities.

By the above method, the transform of a cascade of ovals displaced as in §10 has been obtained. The parameters have the values $b=1.2$, $a=1.1$, $\sigma=\pi/6$. Fig. 14 shows the oval and its transform. The l-plane oval is the curve $ABCD$, the zeros being the points A and C. The transform in the z-plane is the figure $EFGHJK$, where E and H are the zeros. The arc ABC transforms into the curve $EFGH$, and the arc CDA into the curve $HJKE$. It will be seen that the transform is a re-entrant figure, and therefore is of no use in the practical design of cascades (see also §15, however). A feature that is evident from the diagram is that the transform is symmetrical about the perpendicular bisector of the line joining the z-plane zeros. If this is the case, then for the particular values $\sigma=0$ and $\sigma=\pi/2$, the transform should be a thin curved lamina. We shall proceed to prove that this is the case.

§13. Cascades of Thin Curved Plates with Zero Stagger.

Consider first the case $\sigma=0$. Then (23) reduces to

$$\tanh l \tanh (z-l)=\tan^2 a/2 \quad . \quad . \quad . \quad . \quad (71)$$

or

$$\cosh (2\,l-z)=\cos a \cosh z \quad . \quad . \quad (72)$$

Hence

$$2\,l=z+\cosh^{-1}(\cos a \cosh z) \quad . \quad . \quad . \quad . \quad (73)$$

Write

$$\cos a \cosh z=\cosh (C+iD) \quad . \quad . \quad . \quad . \quad (74)$$

Then (73) becomes

$$2\,l=z\pm(C+iD) \quad . \quad . \quad . \quad . \quad . \quad (75)$$

It follows that for any one value of z there are two corresponding values of l; a result which corresponds to the quadratic for l in terms of z in the case of an isolated body (see equation (53)). Equation (75) yields

$$\left.\begin{aligned} 2\,m&=x\pm C\\ 2\,n&=y\pm D\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (76)$$

Now the l-plane zeros of the transformation are for $\sigma=0$ given by (see (61))

$$\left.\begin{aligned} \sinh 2\,m&=\pm\tan a\\ \sin 2\,n&=0\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (77)$$

It follows that the equation of any oval of the family (25), displaced so as to pass through both zeros, is

$$\cosh 2\,m=\sec a \cos 2\,n+\sqrt{(\sec^2 b-\sec^2 a)}\sin 2\,n \quad . \quad . \quad (78)$$

where b is a variable parameter. Now fix on any point in the z-plane. There will be two corresponding points in the l-plane. In general it will be possible to draw two ovals of the form (78), one passing through each point l. If, however, the two ovals coincide, it follows that their transform in the z-plane must be a thin lamina, since two related points on the coincident ovals will yield only one point in the z-plane.

Now the two ovals (78) which correspond to the two points l defined by (76) will have the equations

$$\cosh (x\pm C)=\sec a \cos (y\pm D)+\sqrt{(\sec^2 b-\sec^2 a)}\sin (y\pm D) \quad . \quad (79)$$

If these two ovals are identical, so that b has the same value for each, then b can be eliminated from the two equations (79), the result being

$$\frac{\cosh(x+C)-\sec a\cos(y+D)}{\cosh(x-C)-\sec a\cos(y-D)}=\frac{\sin(y+D)}{\sin(y-D)}$$

which can be reduced to

$$\sec a=\frac{\cosh x\cosh C\cos y}{\cos D}-\frac{\sinh x\sinh C\sin y}{\sin D} \quad . \quad . \quad (80)$$

Now equation (74) yields the equations

$$\left.\begin{aligned}\cos a\cosh x\cos y&=\cosh C\cos D\\ \cos a\sinh x\sin y&=\sinh C\sin D\end{aligned}\right\} \quad . \quad . \quad . \quad (81)$$

Substitution from (81) shows (80) to be identically true. It follows that there is only one oval passing through the zeros (77) and the two points l corresponding to a single point z as defined by (73); and that the transform of this oval is a thin lamina.

This result corresponds to that obtained for four concyclic points in §8.

It is evidently possible to derive a formula giving the equation of the z-plane lamina explicitly in terms of x and y. Elimination of C and D between equations (79) and (81) yields an equation which may be written

$$\cosh 2x=(2\sec^2 a-1)\cos 2y-\frac{\sec a\,(2\sec^2 a-1-\sec^2 b)}{\sqrt{(\sec^2 b-\sec^2 a)}}\sin 2y \quad (82)$$

The transform is thus an arc of an oval of the same type as (78), just as in the simple case the transform of a circle is an arc of a circle. Some typical laminæ obtained from equation (82) are shown in Fig. 15.

The chord of the curved lamina is given by $2\sinh^{-1}(\tan a)$, a result obtained from (82) with $y=0$ or from the co-ordinates of the zeros. The maximum ordinate is in general given by a complicated expression which need not be stated here. For small cambers, however, the maximum ordinate is given simply by the formula

$$y_{\max}=\cos a\sqrt{(\sec^2 b-\sec^2 a)},$$

and is on the axis $x=0$.

§14. Cascades with Chords Parallel to the Imaginary Axis.

When $\sigma=\pi/2$, precisely similar results hold. Equation (23) now becomes

$$\tanh l\tanh(l-z)=\tan^2 a/2 \quad . \quad . \quad . \quad . \quad (83)$$

or

$$\cosh(2l-z)=\sec a\cosh z \quad . \quad . \quad . \quad . \quad (84)$$

The zeros of the transformation are now given by

$$\left.\begin{aligned}\sinh 2m&=0\\ \sin 2n&=\pm\sin a\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (85)$$

and any oval of the family (25) is, when displaced so as to pass through the two points (85),

$$\cos 2n=\cos a\cosh 2m+\sqrt{(\cos^2 a-\cos^2 b)}\sinh 2m \quad . \quad (86)$$

Precisely as before, it may be shown that for any one point z, the two points l defined by (84) both lie on one oval (86); the transform of (86) is thus a thin lamina. The equation of this lamina is then found to be

$$\cos 2y=(2\cos^2 a-1)\cosh 2x-\frac{\cos a\,(2\cos^2 a-1-\cos^2 b)}{\sqrt{(\cos^2 a-\cos^2 b)}}\sinh 2x \quad (87)$$

The chord of the curved lamina is now simply $2a$, and for small cambers, the maximum abscissa is

$$x_{\max}=\sec a\sqrt{(\cos^2 a-\cos^2 b)}.$$

Some typical laminæ are shown in Fig. 16.

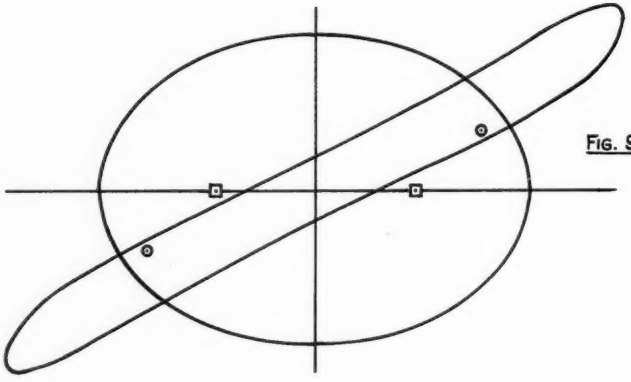


FIG. 9.

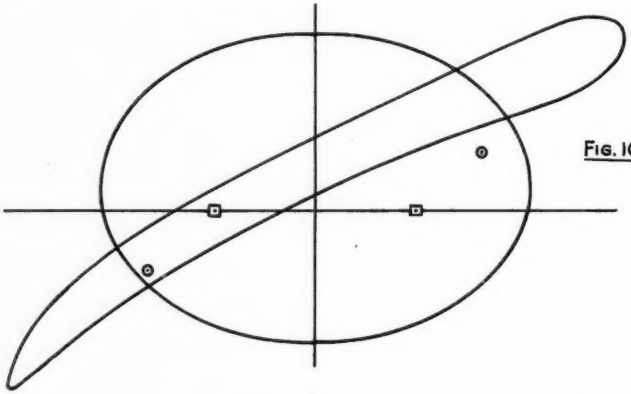


FIG. 10.

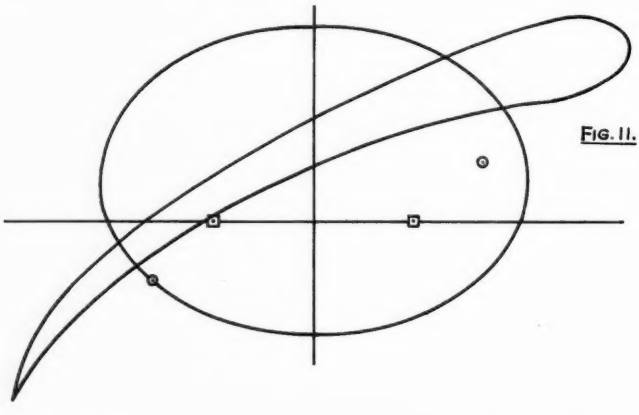


FIG. 11.

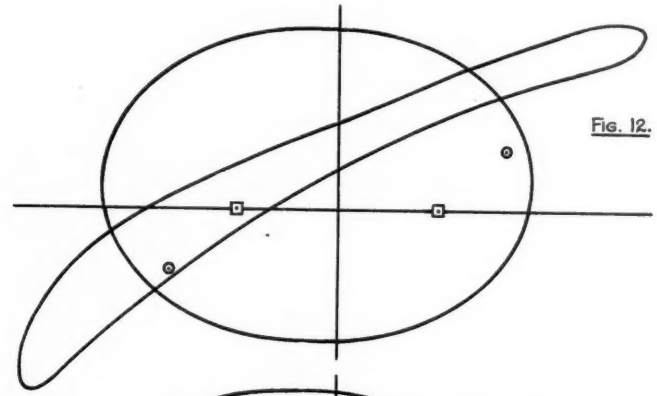


Fig. 12.

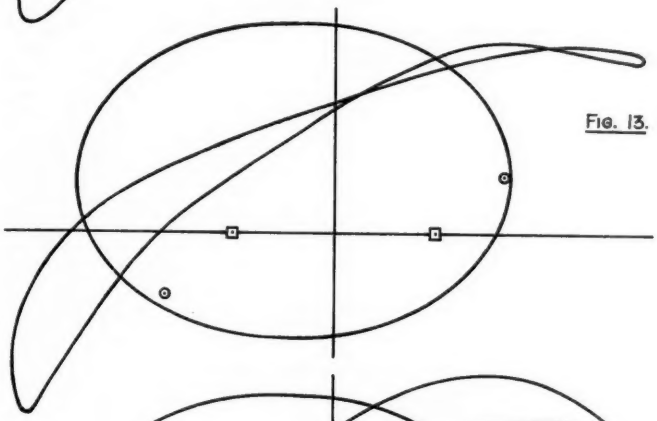


Fig. 13.

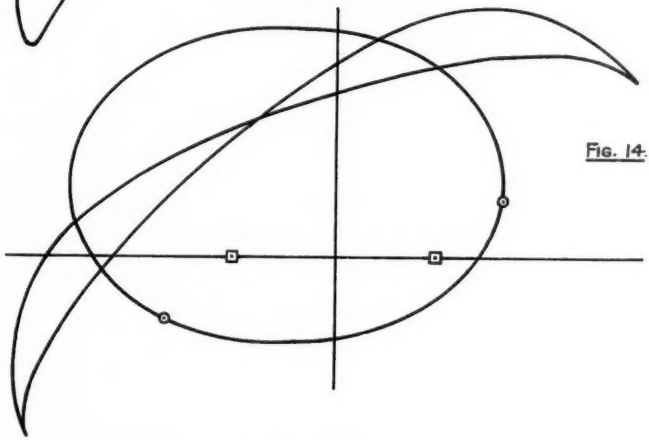


Fig. 14.

§15. General Displacement of the Ovals.

So far, the transformation (23) has been applied to ovals which are displaced so as to pass through the zeros of the transformation. As in the case of the transformation of a circle into various aerofoil shapes, however, it is possible to obtain cascades having a wide variety of shapes by applying the transformation (23) to ovals which contain the zeros within their circumferences, or which have perhaps one zero only on the circumference.

As a very simple instance, consider the case $\sigma=0$, and imagine an oval to be drawn which in its undisplaced position contains both the zeros within its circumference. Now let the oval be displaced along the real axis until one zero comes to the circumference, the other of course remaining inside. The transform is then a symmetrical aerofoil shape, as indicated in Fig. 17, for which $a=1.2$, $b=1.25$. This figure shows parts of two neighbouring ovals, spaced π apart, and the corresponding two aerofoils. The l-plane zeros are indicated by circles and the z-plane zeros by crosses; the sharp trailing edges of the aerofoils are also zeros in the z-plane. The l-plane infinities are indicated by squares. The chord of the aerofoils is approximately 3.38, so that the gap-chord ratio is in this case slightly less than unity.

The general case is illustrated by the sequence of diagrams, Figs. 9-14. In Fig. 9 the undisplaced oval corresponding to $b=1.2$ is drawn, and is transformed according to equation (23), in which $a=1.1$ and $\sigma=\pi/6$. The various singularities are indicated as before by circles, squares, and crosses. The z-plane transform is an unsymmetrical oval figure. In Fig. 10 the l-plane oval is displaced along the imaginary axis; the z-plane transform now begins to bend. In Fig. 11 the oval is further displaced along the imaginary axis until one zero comes to the circumference. The z-plane transform now has a sharp leading (or trailing) edge.

Fig. 12 shows the oval in a general displacement. In Fig. 13 it is displaced until one zero is very close to its circumference; the z-plane transform has now become re-entrant. Finally, when the oval is displaced yet further until both zeros come to the circumference, Fig. 14, which is discussed in §12, is obtained.

As regards the infinities of the transformation, these will evidently lie inside any given oval which encloses the zeros. For it is possible to draw a smaller oval which passes through the zeros and lies wholly within the given oval; the infinities lie inside the smaller oval (see §10) and therefore also lie inside the given oval.

§16. Numerical Formulæ for the Particular Cases $\sigma=0$ and $\sigma=\pi/2$.

For the particular cases $\sigma=0$, $\sigma=\pi/2$, the formulæ for numerical computation given in §11 may be reduced to rather more direct forms. For $\sigma=0$ the appropriate formulæ are

$$\tanh 2x=\frac{2\sinh 2m\,(\cosh 2m-\cos a\cos 2n)}{2\cosh 2m\,(\cosh 2m-\cos a\cos 2n)-\sin^2 a} \quad . \quad (88)$$

$$\tan 2y=\frac{2\sin 2n\,(\cos 2n-\cos a\cosh 2m)}{2\cos 2n\,(\cos 2n-\cos a\cosh 2m)-\sin^2 a} \quad . \quad (89)$$

Similarly, for $\sigma=\pi/2$, the formulæ are

$$\tanh 2x=\frac{2\cos a\sinh 2m\,(\cos 2n-\cos a\cosh 2m)}{2\cos a\cosh 2m\,(\cos 2n-\cos a\cosh 2m)-\sin^2 a} \quad . \quad (90)$$

$$\tan 2y=\frac{2\cos a\sin 2n\,(\cosh 2m-\cos a\cos 2n)}{2\cos a\cosh 2m\,(\cosh 2m-\cos a\cos 2n)-\sin^2 a} \quad . \quad (91)$$

The formulæ (88) and (89) have been used to derive Figs. 18-21. The z-plane transforms are in these figures slightly "waisted," but Figs. 19 and 21 indicate that practical aerofoil shapes can be obtained.

FIG. 15.

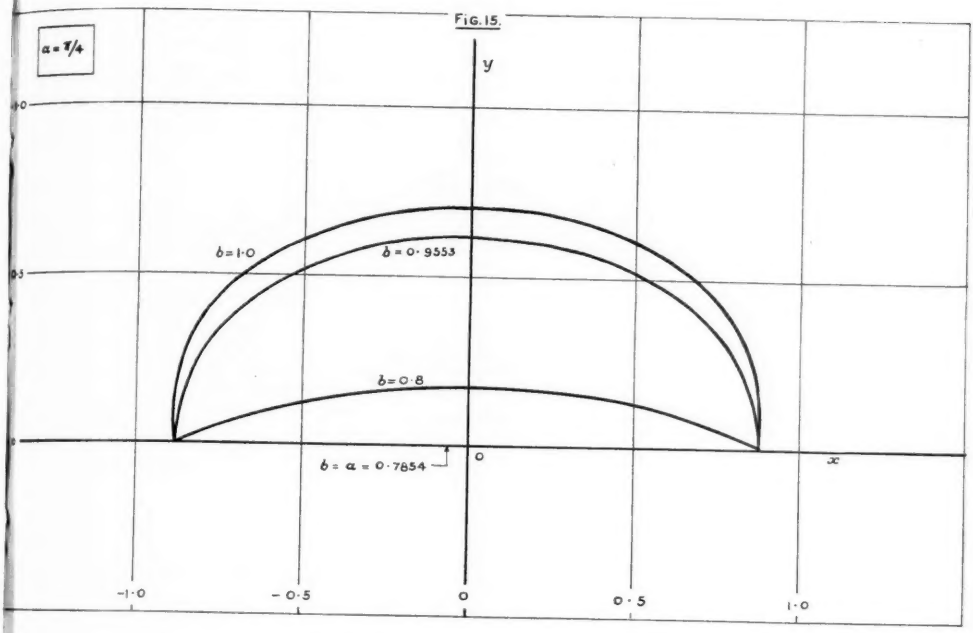

α = π/4
y
b = 1·0
b = 0·9553
b = 0·8
b = a = 0·7854
0
x
-1·0
-0·5
0
0·5
1·0

FIG. 16.

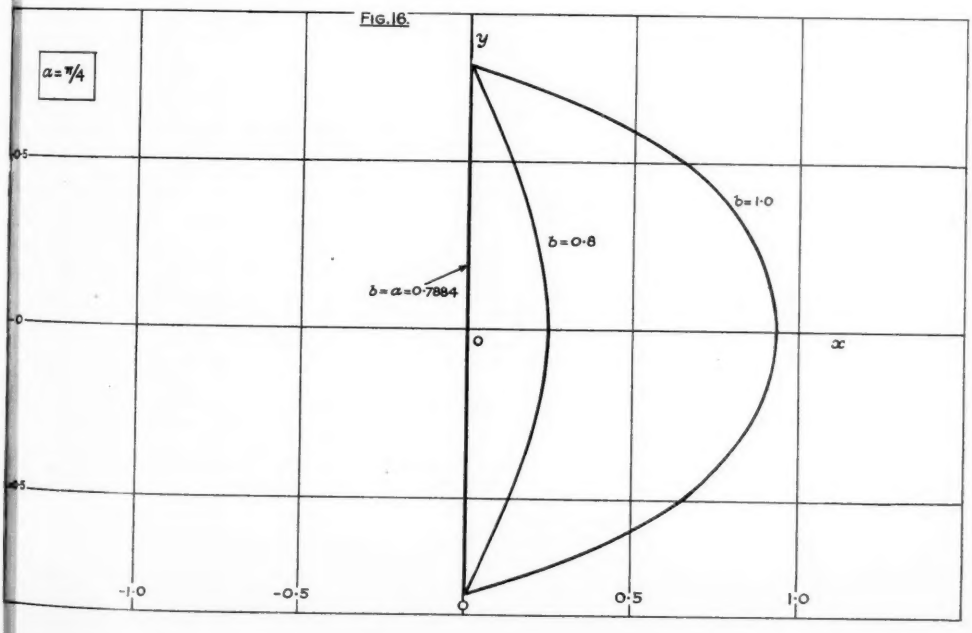

α = π/4
y
b = 1·0
b = 0·8
b = a = 0·7884
0
x
-1·0
-0·5
0
0·5
1·0

Fig. 17.

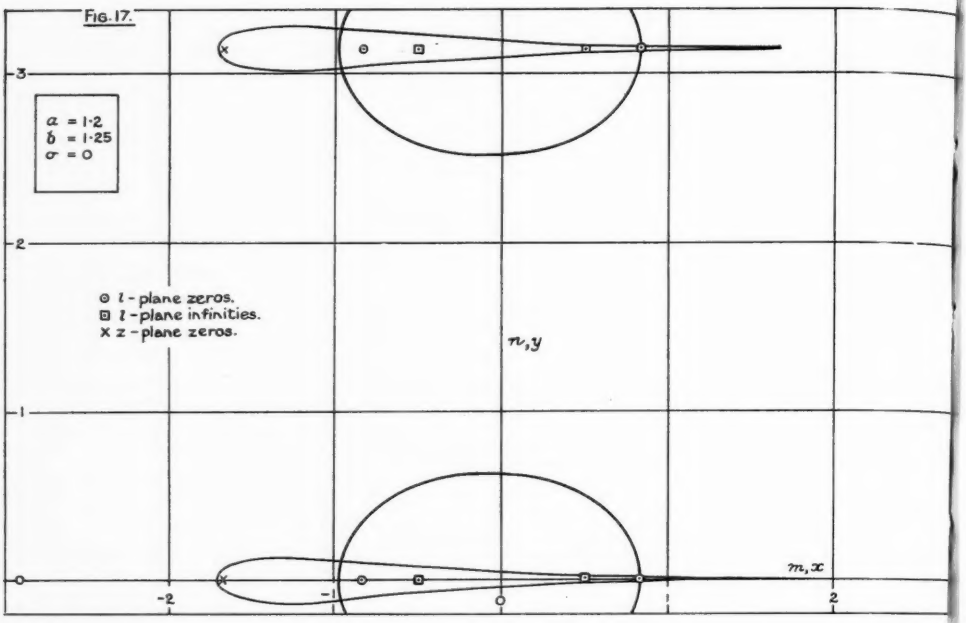


Fig. 18.

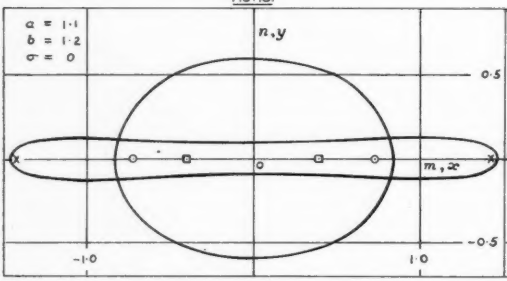


Fig. 20.

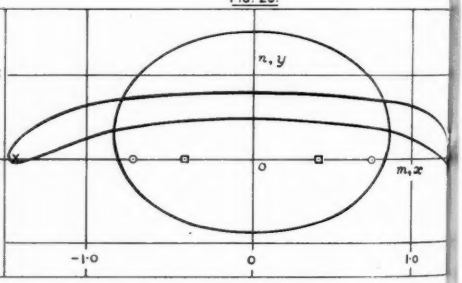


Fig. 19.

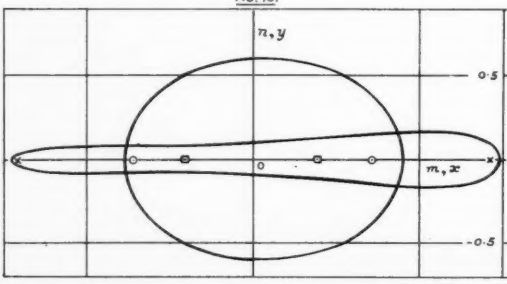
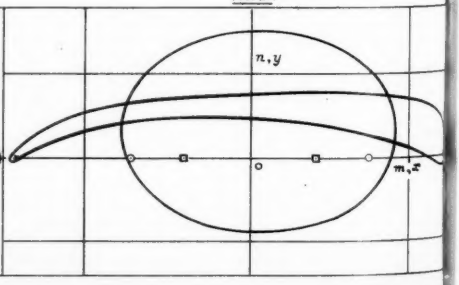


Fig. 21.



§17. Determination of Cascades Fulfilling Certain Hydrodynamical Requirements.

So far, we have considered the derivation of various types of cascade without reference to their hydrodynamic properties as determined, for instance, by application of the Kutta-Joukowski condition. Strictly, this condition can only be applied where a cascade has sharp trailing edges; but it is evident that an approximation to it can be made for aerofoils with rounded trailing edges by choosing a stagnation point arbitrarily on the trailing edge.

We shall now show, by means of a particular example, how to derive cascades which shall have certain hydrodynamic properties. It is frequently necessary, for example, at the corners of a wind tunnel, to deflect a stream of air through a right angle. We shall assume that this is to be done without expansion of the stream. Accordingly, in equation (1), we put $V=0$, $W=U$. The stagnation points in the ζ-plane are then obviously given by

$$\sinh \zeta + i \cosh \zeta = 0 \quad . \quad . \quad . \quad . \quad . \quad (92)$$

which gives the two coincident points

$$\left.\begin{aligned} \xi &= 0 \\ \eta &= -\pi/4 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (93)$$

We shall assume, by application of the Kutta-Joukowski condition to both the leading and trailing edges of the z-plane cascade, that the ζ-plane points (93) will correspond to the leading and trailing edges in the z-plane. The points (93) must therefore lie on the ζ-plane laminæ, and accordingly the length of each lamina, namely $2b$, must exceed $\pi/2$.

Now from §6, the cascade of ζ-plane laminæ may be transformed into a cascade of ovals; and the points on the ovals corresponding to (93) are given by (40) and (26), so that

$$\left.\begin{aligned} 2n &= \eta \\ \cosh 2m &= \sec b \cos 2n \\ &= \sec b \cos \eta \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (94)$$

Substitution from (93) for η gives

$$\left.\begin{aligned} 2n &= -\pi/4 \\ \cosh 2m &= \frac{\sec b}{\sqrt{2}} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (95)$$

Equation (95) can also be deduced directly from equation (42) with $V=0$, $U=W$.

Now suppose the cascade of ovals and the whole flow pattern to be displaced along the n axis by $\pi/8$, so that the stagnation points both come to the real axis. They then have co-ordinates given by

$$\left.\begin{aligned} n &= 0 \\ \cosh 2m &= \frac{\sec b}{\sqrt{2}} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (96)$$

These points are now to be zeros of a transformation (23) in which $\sigma=0$. Now from §13, the zeros are given by equation (77), which may be written in the alternative form

$$\left.\begin{aligned} \cosh 2m &= \sec a \\ n &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (97)$$

which on comparison with (96) yields

$$\sec b = (\sqrt{2}) \sec a \quad . \quad . \quad . \quad . \quad . \quad (98)$$

The transform of the oval is given by equation (82), which in combination with (98) yields

$$\cosh 2x = (2 \sec^2 a - 1) \cos 2y + \sin 2y \quad . \quad . \quad . \quad (99)$$

As shown above, $b > \pi/4$; it follows that $\sec b > \sqrt{2}$. From (98) therefore, a may assume any value from zero to $\pi/2$.

FIG. 22.

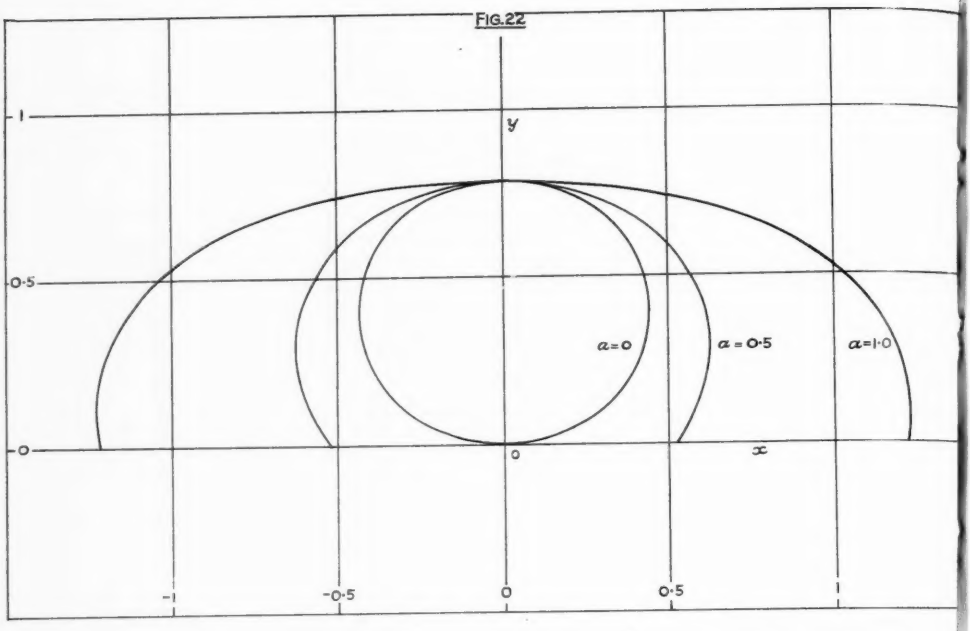
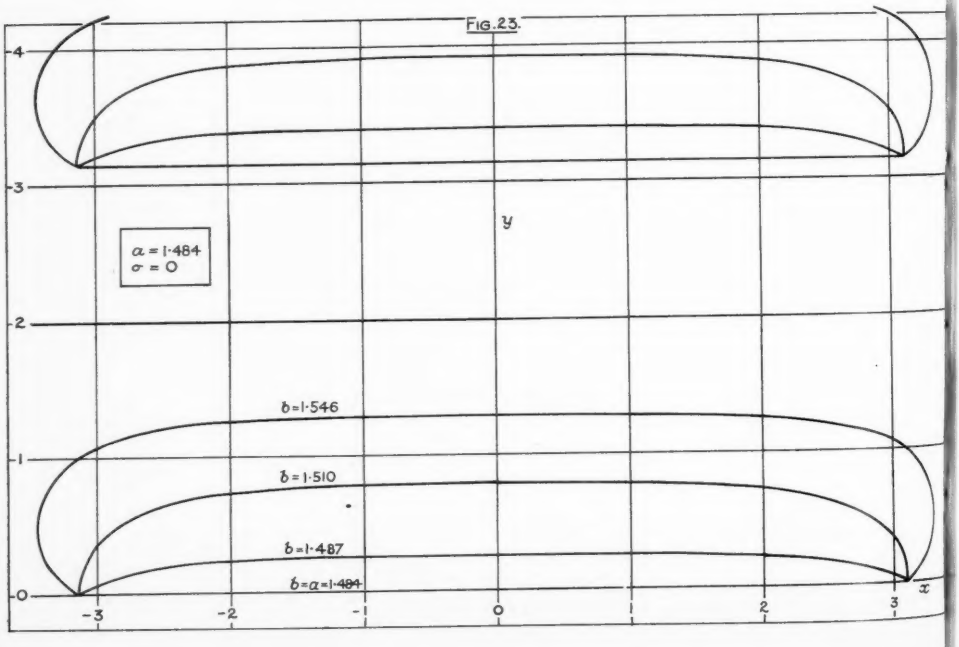

1
0·5
0
y
x
0
a=0
a=0·5
a=1·0
-1
-0·5
0
0·5
1

FIG. 23.


4
3
2
1
0
y
x
a = 1·484
σ = 0
b=1·546
b=1·510
b=1·487
b=a=1·484
-3
-2
-1
0
1
2
3

The ends of the arc defined by (99) are the points given by

$$\left.\begin{aligned} y &= 0 \\ x &= \cosh^{-1}(\sec a) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (100)$$

so that the chord is $2\cosh^{-1}(\sec a)$. The maximum ordinate is in each case given by

$$\left.\begin{aligned} x &= 0 \\ \sin 2y &= 1 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (101)$$

so that its value is $\pi/4$.

A number of typical shapes are given in Fig. 22. They are for $a=0$, 0.5, and 1. The case $a=0$ yields a closed curve, and the Kutta-Joukowski condition is thus meaningless. The other cases yield possible types of cascade, though neither is like the skeleton of aerofoils of the type commonly used in practice to deflect air through a right angle. These usually have a gap-chord ratio of about $\frac{1}{2}$, and the maximum ordinate of the skeleton is between 0.25 and 0.3 of the chord (see for instance Reference 6). Fig. 23 shows a number of skeleton aerofoils (curved laminæ) of the type discussed in §13 and having a gap-chord ratio of $\frac{1}{2}$. Of these, the one corresponding to $b=1.510$ has the property discussed in the present paragraph of deflecting the fluid through a right angle when the flow at its leading and trailing edges has a finite velocity. The maximum ordinate of this curve is only 0.125 of the chord. Moreover, its leading and trailing edge are very nearly normal to the chord, whereas in practice it is common to use an aerofoil the skeleton of which has leading and trailing edges approximately parallel to the directions of inflow and outflow at some distance from the cascade; that is, making an angle of 45° with the chord.

§18. Some Properties of Cascades of Aerofoils.

To conclude, we shall consider the properties of cascades of aerofoils when the simple Kutta-Joukowski condition is applied. The cascades must therefore have sharp trailing edges. It will have become evident from previous diagrams that for aerofoils of normal fine shape, the leading edge passes quite close to one of the zeros of the transformation, the trailing edge being coincident with the other. We shall therefore define the chord of any aerofoil as the line joining the zeros; this chord line is then not very different from that conventionally used. Accordingly, the gap-chord ratio s/c of any cascade is given by (38) as

$$s/c = \pi/2 \{ \cos\sigma \sinh^{-1}(\tan a \cos\sigma) + \sin\sigma \sin^{-1}(\sin a \sin\sigma) \} \quad (102)$$

Moreover, the stagger of the cascade, namely, the angle between the chord line of an aerofoil and the normal to the cascade, is simply σ. For any given gap-chord ratio and stagger, therefore, the parameter a is determined by (102). Fig. 24 gives curves of a against s/c determined from (102), for $\sigma=0$, $\pi/6$, $\pi/3$, $\pi/2$. When s/c is small, a is very nearly equal to $\pi/2$; its value may be determined with good accuracy from the approximate relation

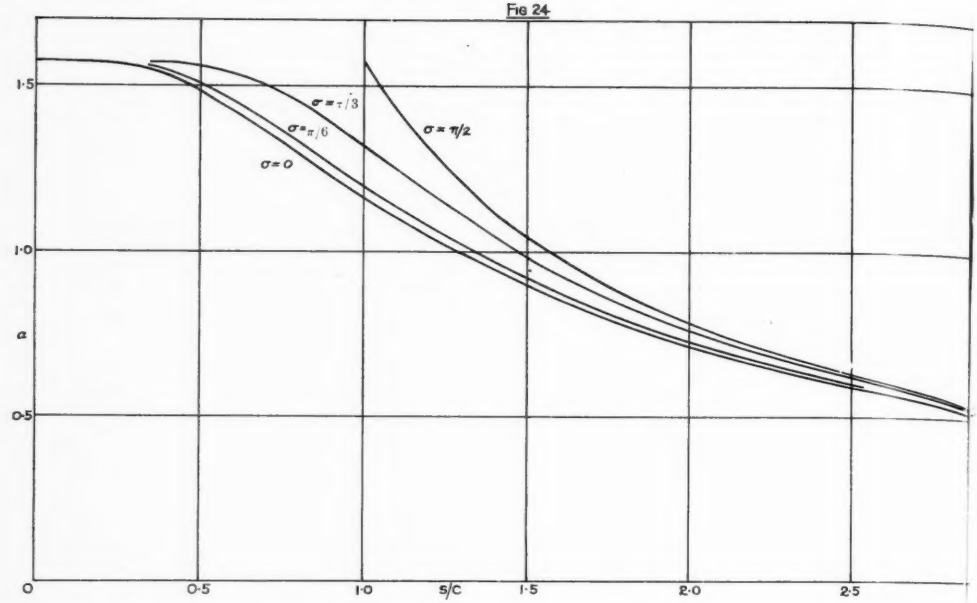
$$a = \frac{\pi}{2} - \cos\sigma \operatorname{cosech}\left(\frac{\pi c}{2s}\sec\sigma - \sigma\tan\sigma\right)$$

for values of s/c from 0 to 0.7.

The parameter b, and the position of the oval in relation to the zeros, determine the thickness of the aerofoil and the amount of camber.

Imagine, therefore, a cascade of ovals, defined by the parameter b, and so displaced that the circumference of each passes through one zero of the transformation (23). The resulting cascade will have sharp trailing edges (see for example Figs. 11 and 17). The Kutta-Joukowski condition requires that the velocity of flow at these trailing edges must be finite. Hence the corresponding points on the ovals, namely, the zeros of the transformation, must always be stagnation points. In other words, the flow past the ovals given by equation (42) must always have a stagnation point at a given fixed point on each oval.

Fig 24.



Suppose that when the direction of inflow at infinity makes an angle θ_0 with the real axis, the angle of outflow is also θ_0. The z-plane aerofoils then have no lift, and in consequence there is no circulation. The conventional " no-lift angle " is $\theta_0 - \sigma$. Accordingly in (42) we write b for a and put $V = U \tan \theta_0$, $W = 0$; to find the stagnation points we put $dw/dl = 0$, when the equation may be reduced to

$$\tanh^2 l = \tan^2 \frac{b}{2}\left(\frac{\sec b + i \tan \theta_0}{\sec b - i \tan \theta_0}\right) . \quad . \quad . \quad . \quad (103)$$

which defines the stagnation points in terms of θ_0. For general values of U, V, and W, the stagnation points are given by (42) with $dw/dl = 0$, which, if we write $V = U \tan \theta_1$, $W = XU$, becomes

$$iX \tanh l = i \tan \theta_1 \left(\frac{\tanh^2 l + \tan^2 b/2}{1 + \tan^2 b/2}\right) - \left(\frac{\tanh^2 l - \tan^2 b/2}{1 - \tan^2 b/2}\right) . \quad (104)$$

Since one of the stagnation points defined by (104) is to be the same as one defined by (103), we eliminate l between these equations. The result may be written in the form

$$X = \frac{\tan b \, (\tan \theta_1 - \tan \theta_0)}{\sqrt{(\sec^2 b + \tan^2 \theta_0)}} \quad . \quad . \quad . \quad . \quad (105)$$

an equation which fixes the value of the circulation for any given value of θ_1. We may now determine, for instance, the relation between α_1 and α_2, the angles between the normal to the cascade and the directions of inflow and outflow at infinity. For, by (4) and (5),

$$\tan \alpha_1 = \frac{V + W}{U} = X + \tan \theta_1 \quad . \quad . \quad . \quad . \quad (106)$$

$$\tan \alpha_2 = \frac{V - W}{U} = -X + \tan \theta_1 \quad . \quad . \quad . \quad . \quad (107)$$

and elimination of X and θ_1 between (105), (106), and (107) yields

$$\frac{\tan \alpha_2 - k \tan \theta_0}{\tan \alpha_1 + k \tan \theta_0} = \frac{1-k}{1+k} \quad . \quad . \quad . \quad . \quad . \quad (108)$$

where

$$k = \tan b / \sqrt{(\sec^2 b + \tan^2 \theta_0)} \quad . \quad . \quad . \quad . \quad . \quad (109)$$

There is thus a linear relation between the tangents of the angles of inflow and outflow.

We may also determine the lift coefficient of the aerofoils. The force on each aerofoil per unit depth will be written F; it is at right angles to the mean direction of the stream, *i.e.*, it makes an angle θ_1 with the imaginary axis. Then, according to the usual definition of C_L, since the mean velocity is $U \sec \theta_1$,

$$F = \tfrac{1}{2} c C_L \rho U^2 \sec^2 \theta_1$$

The component of the force parallel to the imaginary axis is accordingly

$$F \cos \theta_1 = \tfrac{1}{2} c C_L \rho U^2 \sec \theta_1 \quad . \quad . \quad . \quad . \quad . \quad (110)$$

But the rate of change of momentum parallel to the imaginary axis is

$$F \cos \theta_1 = 2 \pi \rho U W = 2 \pi \rho U^2 X \quad . \quad . \quad . \quad . \quad . \quad (111)$$

Comparison of (110) and (111) gives

$$C_L = 4 (\pi/c) X \cos \theta_1 = 4 (s/c) X \cos \theta_1 \quad . \quad . \quad . \quad . \quad (112)$$

Now equation (105) may be written

$$X = k \sin (\theta_1 - \theta_0) \sec \theta_0 \sec \theta_1 \quad . \quad . \quad . \quad . \quad . \quad (113)$$

where k is defined by (109). Substitution for X from (113) in (112) gives

$$C_L = 4 (s/c) k \sec \theta_0 \sin (\theta_1 - \theta_0)$$

which on substitution for k becomes

$$C_L = 4 \left(\frac{s}{c}\right) \frac{\sin (\theta_1 - \theta_0)}{\sqrt{(\cot^2 b + \cos^2 \theta_0)}} \quad . \quad . \quad . \quad . \quad . \quad (114)$$

Thus C_L is proportional to the sine of the angle between the mean direction of flow and the angle corresponding to the condition of no lift; a result which is well-known in the case of isolated aerofoils.

List of References.

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3. Lamb, H. Hydrodynamics (C.U.P.), 4th Edition, 1916, §306.
4. Collar, A. R. Cascade Theory and the Design of Fan Straighteners. R. & M. 1885.
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REVIEWS.

ELEMENTARY HANDBOOK FOR WIRELESS OPERATORS.

By W. E. Crook. Sir Isaac Pitman and Sons. 4/-.

The word " elementary " too often designates either a sketchy outline written by an author knowing little of his subject, or one of those unclassifiable works in which an expert starts by writing down to his readers as if they were mentally deficient and ends by crediting them with as much knowledge as himself. This book is a happy exception. The author is an expert, but he is also a practical man with a gift for imparting his knowledge. His lucid distinction of the terms " energy," " work " and " power," is a case in point.

Having summed up the principles of electricity, he describes in detail the component parts of a wireless set, its sources of power and accessory instruments, concluding with some notes on calculation and formulæ. Chapter VII, which skims the subject of direction-finding, might with advantage be extended in a subsequent edition.

AIRCRAFT OF THE FIGHTING POWERS.

Compiled by H. J. Cooper and O. G. Thetford and edited by D. A. Russell, A.M.I.Mech.E. The Marlborough Publishing Company, Ltd., Leicester. 1941. 10/6 net.

This is an excellently well produced book giving detailed descriptions, photographs and general arrangement drawings of the military machines now in general use.

Not three years ago constant efforts were being made in this country to make people air-minded. Where the efforts of many of our best speakers were not successful over many years, the Germans in a few months have succeeded. Everyone is very much air-minded these days and there are few who are not anxious to know a little more about the new power which has brought the civilian populations of the world into the front line of battle.

This book will provide them with that information in its clearest and simplest form. Whether the seeker after knowledge is merely interested in the subject, or whether he is a member of the R.A.F., Observer Corps, the Air Defence Cadet Corps, or other services, here he will find a guide to those aircraft he sees so often overhead.

All the general arrangement drawings are to scale or to the same scale, enabling the reader to judge more quickly than from mere figures, the selective sizes of various aircraft now being used.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES.

JUNE, 1941.

Election of Members.

The following Members were recently elected:—

Fellow.—Ernest Platton King (from Associate Fellow).

Associate Fellows.—Eric Raymond Arbon (from Graduate), Granville Clifford (from Graduate), Albert R. Crocker (from Graduate), Walter Goodesmith, Ian Otto Hockmeyer, Adrian Victor Kilburn (from Student), Marya Zbigniew Krzywoblocki (from Companion), Thomas Henry Redding (from Graduate), Terence Blair Rendel, Gordon Edwardes Lind Walker (from Student), John Denis Walsh (from Student), Eric Thomas Watkinson, Charles Harold Wigg (from Student).

Associates.—Eric Archer, Andrew Milligan.

Graduates.—William Macpherson Barber, James Arthur Beardsall (from Student), John Oliver Doley.

Students.—John Bryce, Arthur Capella, Peter Anthony Curry, John Henry Hawes, Gordon Robertson Matheson, Guy Malcolm Parker, Andrew Ivor Pollard, John Burton Quick, William Alfred Sparks.

Fire Watching.

One or two members of the Society, living in London, have recently offered to take turns with the staff at fire watching duty at the Headquarters of the Society. The Secretary will greatly appreciate any help in this direction which may be offered to safeguard the Society's premises.

Elliott Memorial Prize.

The Elliott Memorial Prize has been awarded to Sergeant Apprentice J. J. S. Hirons (576110), who obtained the highest marks in the General Studies Examination of the August, 1939, entry at Halton.

Acknowledgments.

The Council would like to place on record their thanks to Mr. C. G. Grey for his gift of " Jane's All the World's Aircraft " for 1918. This volume was the only one missing from the Society's set and this opportunity to complete will be most appreciated by members and others who consult Jane's frequently.

Additions to the Library.

(Pamphlets in italics, with location reference following in brackets.
Books marked * may not be taken out on loan.)

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J. LAURENCE PRITCHARD, *Secretary and Editor.*

VARIABLE DISTRIBUTED LOADS IN THE THEOREM OF THREE MOMENTS.

By F. J. Turton, B.Sc., A.R.C.Sc.

The Theorem of Three Moments in a simple form, referring to bending moments at any three consecutive supports A, B, C, of a continuous beam uniform in each bay, $AB=a$, $BC=c$, takes the form

$$\frac{aM_A}{EI}+2\left(\frac{a}{EI}+\frac{c}{EI'}\right)M_B+\frac{cM_C}{EI'}=\frac{wa^3}{4EI}+\frac{w'c^3}{4EI'} \quad . \quad . \quad (1)$$

w and w' being *constant* load intensities over AB and CB respectively.

On p. 159, Vol. 42 (1938), of this journal, Capt. J. Morris discussed a modification in this case (and in the more general case when the beam is in thrust) when the load intensity varies according to a parabolic law. At that date, the present writer had in the press a paper* giving the theorem when EI is constant over each bay, but with *any* concentrated loads W_1 at x_1, W_2 at x_2, etc., from A in AB, applied couples C_1 at ξ_1, C_2 at ξ_2, etc., from A in AB, with or without thrust, and in particular, an integral form for *any* distributed load in AB, together with similar loads and couples in the bay CB, and allowing for a possible couple, m_B at B, as occurs in aeroplane structures.

Without thrust, the theorem is

$$\frac{aM_{AR}}{EI}+\frac{2aM_{BL}}{EI}+\frac{2cM_{BR}}{EI'}+\frac{cM_{CL}}{EI'}=6\frac{y_A-y_B}{a}+6\frac{y_C-y_B}{c}+\Sigma\frac{W_1x_1(a^2-x_1^2)}{aEI}$$
$$+\Sigma\frac{W'_1z_1(c^2-z_1^2)}{cEI'}+\int_0^a\frac{wX(a^2-X^2)\,dX}{aEI}+\int_0^c\frac{w'Z(c^2-Z^2)\,dZ}{cEI'}$$
$$-\Sigma\frac{C_1(a^2-3\xi_1^2)}{aEI}-\Sigma\frac{C'_1(c^2-3\xi_1^2)}{cEI'}$$

where $M_{BR}=M_{BL}+m_B$, w is a function of X, w' of Z, measured from A and C respectively.

The integral for variable w integrates at once in a simple form when w can be represented throughout the bay by any polynomial. Alternatively, one may express the integral in terms of a corresponding number of particular values of w in the bay; Morris's result is one such form. When the variable load intensity is approximately represented by a polynomial, the agreement of values from two or more such formulæ may show that the integral is evaluated with *sufficient* accuracy from each of them.

When the beam is in thrust, it will be shown that the corresponding integral can readily be used to put the contribution from variable distributed load into terms of Berry† functions when w can be represented by any polynomial throughout the bay; Morris's result is again a special case of a general method.

A. (i) Thrust absent: load intensity terms when w is given as a polynomial.

If

$$w=\omega_0+\omega_1x/a+\omega_2x^2/a^2+\ldots$$
$$=\omega_0+\omega_1r+\omega_2r^2+\ldots \text{ where } r=x/a$$

* Phil. Mag., Ser. 7, XXV, p. 852 (1938).

† Berry: Trans. Roy. Aero. Soc., No. 1. The tables of values of these functions are reprinted by Pippard and Pritchard, "Aeroplane Structures."

$$\int_0^a \frac{wX\,(a^2-X^2)\,dX}{aEI} \text{ becomes } \frac{a^3}{EI}\int_0^1 (\omega_0+\omega_1 r+\omega_2 r^2+\ldots)\,r\,(1-r^2)\,dr$$

$$=\frac{2\,a^3}{EI}\left(\frac{\omega_0}{2.4}+\frac{\omega_1}{3.5}+\frac{\omega_2}{4.6}+\ldots\right) \quad . \quad . \quad . \quad . \quad (3)$$

Similarly

$$\int_0^c \frac{w'Z\,(c^2-Z^2)\,dZ}{cEI'}=\frac{2\,c^3}{EI'}\left(\frac{\omega'_0}{2.4}+\frac{\omega'_1}{3.5}+\frac{\omega'_2}{4.6}+\ldots\right)$$

A. (ii) Thrust absent: load intensity terms as multiples of particular values of the load intensity.

It is well known that Simpson's rule

$$y_1-y_0=h\,(y'_0+4\,y'_{1/2}+y'_1)/3-[h^5y^{\mathrm{V}}/90]^* \quad . \quad . \quad . \quad (4)$$

gives exact results when y' can be expressed in terms of the independent variable as a polynomial of degree 3.

Since w is multiplied by a cubic in r, Simpson's rule cannot here be used to obtain the *exact* value of the integral in w.

But the Newton-Cotes formulæ† following Simpson's $\frac{3}{8}$th rule, can be so used. It is well known that an odd-strip formula of this series gives error terms of the same order of accuracy as the preceding even-strip formula, but is less simple, so will not be used when the load intensity is *exactly* represented by a given polynomial; it may, however, be used to test the validity of an approximate representation, for it will be simpler than the next even-strip formula in the series, and which can be used for the same purpose.

$$y_1-y_0=2\,h\,\{7\,(y'_0+y'_1)+32\,(y'_{1/4}+y'_{3/4})+12\,y'_{1/2}\}/45-[8\,h^7y^{\mathrm{VII}}/945] \quad (5)$$

and

$$y_1-y_0=5\,h\,\{19\,(y'_0+y'_1)+75\,(y'_{1/5}+y'_{4/5})+50\,(y'_{2/5}+y'_{3/5})\}/288 \\ -[275\,h^7y^{\mathrm{VII}}/12{,}096] \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Both give exact values for the integral when w is a polynomial of degree 1 or 2, *i.e.*, when the load intensity is linear or parabolic.

$$y_1-y_0=h\,\{41\,(y'_0+y'_1)+216\,(y'_{1/6}+y'_{5/6})+27\,(y'_{1/3}+y'_{2/3}+272\,y'_{1/2}\}/140 \\ -[9\,h^9y^{\mathrm{IX}}/1{,}400] \quad . \quad . \quad . \quad . \quad . \quad (7)$$

gives exact values for the integral when w is a polynomial of degree 1, 2, 3 or 4.

$$y_1-y_0=4\,h\,\{980\,(y'_0+y'_1)+5{,}888\,(y'_{1/8}+y'_{7/8})-928\,(y'_{1/4}+y'_{3/4})+10{,}496\,(y'_{3/8}+y'_{5/8})\}/14{,}175-4{,}540\,y'_{1/2} \\ -[2{,}368\,h^{11}y^{\mathrm{XI}}/467{,}775]$$

gives exact values for the integral when w is a polynomial of degree 1, 2, 3, 4, 5 or 6. The presence of negative coefficients in this and subsequent members of the Newton-Cotes formulæ means, unfortunately, numerically larger coefficients and increased liability to rounding-off errors.

Other well-known formulæ for approximate integration due to Weddle, Hardy and Shovelton, all have principal error terms of the order h^7y^{VII}, but owing to the multiplication by $(r-r^3)$ at intermediate points in this problem, appear to give less suitable formulæ than (5.1) and (6.1) which follow from (5) and (6).

Using (5), $h=\frac{1}{4}$, and denoting w at $r=x/a$ by w_r,

$$\int_0^1 w\,(r-r^3)\,dr=\{32\,(\tfrac{1}{4}\cdot\tfrac{15}{16}\,w_{1/4}+\tfrac{3}{4}\cdot\tfrac{7}{16}\,w_{3/4})+12\,(\tfrac{1}{2}\cdot\tfrac{3}{4}\,w_{1/2})\}/90$$

$$=(5\,w_{1/4}+3\,w_{1/2}+7\,w_{3/4})/60 \quad . \quad . \quad . \quad . \quad (5.1)$$

* The principal error term is given in brackets, thus [ ].

† Whittaker and Robinson: Calculus of Observations, p. 155.

Using (6), $h=\frac{1}{5}$,

$$\int_0^1 w\,(r-r^3)\,dr = \{\,75\,(\tfrac{1}{5}\cdot\tfrac{24}{25}\,w_{1/5}+\tfrac{4}{5}\cdot\tfrac{9}{25}\,w_{4/5})+50\,(\tfrac{2}{5}\cdot\tfrac{21}{25}\,w_{2/5}+\tfrac{3}{5}\cdot\tfrac{16}{25}\,w_{3/5})\,\}\ /288$$

$$=(6\,w_{1/5}+7\,w_{2/5}+8\,w_{3/5}+9\,w_{4/5})/120 \quad . \quad . \quad . \quad . \quad (6.1)$$

Using (7), $h=\frac{1}{6}$.

$$\int_0^1 w\,(r-r^3)\,dr = \{\,216\,(\tfrac{1}{6}\cdot\tfrac{35}{36}\,w_{1/6}+\tfrac{5}{6}\cdot\tfrac{11}{36}\,w_{5/6})+27\,(\tfrac{1}{3}\cdot\tfrac{8}{9}\,w_{1/3}+\tfrac{2}{3}\cdot\tfrac{5}{9}\,w_{2/3})$$
$$+272\cdot\tfrac{1}{2}\cdot\tfrac{3}{4}\,w_{1/2}\,\}\ /840$$

$$=(35\,w_{1/6}+8\,w_{1/3}+102\,w_{1/2}+10\,w_{2/3}+55\,w_{5/6})/840 \quad . \quad (7.1)$$

Using (8), $h=\frac{1}{8}$.

$$\int_0^1 w\,(r-r^3)\,dr = \left\{\begin{array}{l} 5{,}888\,(\frac{1}{8}\cdot\frac{63}{64}\,w_{1/8}+\frac{7}{8}\cdot\frac{15}{64}\,w_{7/8})-928\,(\frac{1}{4}\cdot\frac{15}{16}\,w_{1/4}+\frac{3}{4}\cdot\frac{7}{16}\,w_{3/4} \\ +10{,}496\,(\frac{3}{8}\cdot\frac{55}{64}\,w_{3/8}+\frac{5}{8}\cdot\frac{39}{64}\cdot w_{5/8})-4{,}540\cdot\frac{1}{2}\cdot\frac{3}{4}\,w_{1/2} \end{array}\right\}\Big/28{,}350$$

$$=\left(\begin{array}{l} 1{,}449\,w_{1/8}-435\,w_{1/4}+6{,}765\,w_{3/8}-3{,}405\,w_{1/2} \\ +7{,}995\,w_{5/8}-609\,w_{3/4}+2{,}415\,w_{7/8} \end{array}\right)\Big/56{,}700 \quad . \quad (8.1)$$

Thus, if w can be calculated exactly from a polynomial of degree 1 or 2, the term in w in the theorem is

$$a^3\,(5\,w_{1/4}+3\,w_{1/2}+7\,w_{3/4})/60\,EI \quad . \quad . \quad . \quad (5.2)$$

or

$$a^3\,(6\,w_{1/5}+7\,w_{2/5}+8\,w_{3/5}+9\,w_{4/5})/120\,EI \quad . \quad . \quad . \quad (6.2)$$

If w appears to be approximately represented by such a polynomial and if values from (5.2) and (6.2) agree with *sufficient* accuracy, it is *probable* that the common value is correct to that accuracy; it may be thought worth while to check further by the next formula (7.2); if the same value be obtained, the probability that it is correct is greatly increased.

Morris's result in terms of the symbols of this paper is

$$a^3\,(w_0+12\,w_{1/2}+2\,w_1)/60\,EI.$$

This may also be used in the same way. If for w we put $\omega_0+\omega_1 r+\omega_2 r^2$, all three expressions reduce to

$$\frac{2\,a^3}{EI}\left(\frac{\omega_0}{2.4}+\frac{\omega_1}{3.5}+\frac{\omega_2}{4.6}\right)$$

as they should, by equation (3).

If w is a polynomial of degree 1, 2, 3 or 4, the term in w becomes

$$a^3\,(35\,w_{1/6}+8\,w_{1/3}+102\,w_{1/2}+10\,w_{2/3}+55\,w_{5/6})/840\,EI \quad . \quad (7.2)$$

and

$$a^3\,(1{,}449\,w_{1/8}-435\,w_{1/4}+6{,}765\,w_{3/8}-3{,}405\,w_{1/2}+7{,}995\,w_{5/8}-609\,w_{3/4}$$
$$+2{,}415\,w_{7/8})/56{,}700\,EI \quad . \quad . \quad . \quad . \quad (8.2)$$

when w is a polynomial of degree 1, 2, 3, 4, 5 or 6.

B. When thrust, P, is included.

The theorem is now

$$6\,\frac{ma\,\operatorname{cosec} ma-1}{aP}\,M_{AR}+6\,\frac{1-ma\cot ma}{aP}\,M_{BL}+6\,\frac{1-m'c\cot m'c}{cP'}\,M_{BR}$$
$$+6\,\frac{m'c\,\operatorname{cosec} m'c-1}{cP'}\,M_{CL}=6\,\frac{y_A-y_B}{a}+\Sigma\,\frac{6\,W_1}{P}\left(\frac{\sin m x_1}{\sin ma}-\frac{x_1}{a}\right)$$
$$+\int_0^a\frac{6\,w}{P}\left(\frac{\sin mX}{\sin ma}-\frac{X}{a}\right)dX-\Sigma\,\frac{6\,C_1}{P}\left(\frac{m\cos m\xi_1}{\sin ma}-\frac{1}{a}\right)+6\,\frac{y_C-y_B}{c}$$
$$+\Sigma\,\frac{6\,W'_1}{P'}\left(\frac{\sin m'z_1}{\sin m'c}-\frac{z_1}{c}\right)+\int_0^c\frac{6\,w'}{P'}\left(\frac{\sin m'Z}{\sin m'c}-\frac{Z}{c}\right)dZ-\Sigma\,\frac{6\,C'_1}{P'}\left(\frac{m'\cos m'\zeta_1}{\sin m'c}-\frac{1}{c}\right)$$

Berry obtained this theorem for *constant* distributed loads, in the equivalent form,

$$\frac{aM_{AR}}{EI}f(\alpha)+\frac{2aM_{BL}}{EI}\phi(\alpha)+\frac{2cM_{BR}}{EI'}\phi(\alpha')+\frac{cM_{CL}}{EI'}f(\alpha')$$
$$=6\frac{y_A-y_B}{a}+6\frac{y_C-y_B}{c}+\frac{wa^3}{4EI}\psi(\alpha)+\frac{w'c^3}{EI'}\psi(\alpha')$$

where $m^2EI=P$, $m'^2EI'=P'$, $2\alpha=ma$, $2\alpha'=m'c$, and $f(\alpha)$, $\phi(\alpha)$ and $\psi(\alpha)$ are the Berry functions.

$$f(\alpha)=6(2\alpha\operatorname{cosec}2\alpha-1)/(2\alpha)^2$$
$$\phi(\alpha)=3(1-2\alpha\cot 2\alpha)/(2\alpha)^2$$
$$\psi(\alpha)=3(\tan\alpha-\alpha)/\alpha^3.$$

Thus for non-uniform distributed loads we have

$$\int_0^a\frac{6w}{P}\left(\frac{\sin mX}{\sin ma}-\frac{X}{a}\right)dX \text{ in place of } wa^3\psi(\alpha)/4EI,$$

which itself replaces $wa^3/4EI$ when thrust is absent.

(i) If $w=\omega_0+\omega_1r+\omega_2r^2+\ldots$, where $r=x/a$, the term becomes

$$\int_0^1\frac{6a}{P}(\omega_0+\omega_1r+\omega_2r^2+\ldots)\left(\frac{\sin mar}{\sin ma}-r\right)dr$$

Now

$$\int_0^1\frac{r^n\sin mardr}{\sin ma}=\left(-\frac{r^n\cos mar}{ma\sin ma}+\int\frac{nr^{n-1}\cos mar}{ma\sin ma}dr\right)_0^1$$
$$=\left(-\frac{\cos ma}{ma\sin ma}+\frac{nr^{n-1}\sin mar}{m^2a^2\sin ma}-\int\frac{n(n-1)r^{n-2}\sin mar\,.\,dr}{m^2a^2\sin ma}\right)_0^1.$$
$$=\frac{n-ma\cot ma}{m^2a^2}-\frac{n(n-1)}{m^2a^2}\int_0^1\frac{r^{n-2}\sin mar\,.\,dr}{\sin ma},$$

a reduction formula for the general term in the integral for w.

The residual integral will be

(*a*) if n is even, $\displaystyle\int_0^1\frac{\sin mar\,.\,dr}{\sin ma}=\left[-\frac{\cos mar}{ma\sin ma}\right]_0^1=\frac{1-\cos ma}{ma\sin ma}=\frac{1}{ma}\tan\frac{ma}{2}$

(*b*) if n is odd, $\displaystyle\int_0^1\frac{r\sin mar\,.\,dr}{\sin ma}=\left(-\frac{r\cos mar}{ma\sin ma}+\frac{\sin mar}{m^2a^2\sin ma}\right)_0^1=\frac{1-ma\cot ma}{m^2a^2}$

If, following Berry, we write $2\alpha=ma$, it is evident that for all values of n, the term in w may readily be put in terms of powers of α and the Berry functions $\phi(\alpha)$ and $\psi(\alpha)$.

In particular, if $w=\omega_0+\omega_1r+\omega_2r^2$, the term in w in the theorem is

$$\int_0^1\frac{6a}{P}(\omega_0+\omega_1r+\omega_2r^2)\left(\frac{\sin mar}{\sin ma}-r\right)dr$$
$$=\frac{6a}{P}\left[\omega_0\left(\frac{1}{ma}\tan\frac{ma}{2}-\tfrac{1}{2}\right)+\omega_1\left(\frac{1-ma\cot ma}{m^2a^2}-\tfrac{1}{3}\right)\right.$$
$$\left.+\omega_2\left(\frac{2-ma\cot ma}{m^2a^2}-\frac{2\tan(ma/2)}{m^2a^3}-\tfrac{1}{4}\right)\right].$$

$$= \frac{6a}{P}\left[\omega_0 \frac{\tan \alpha - \alpha}{2\alpha} + \omega_1 \left(\tfrac{1}{3}\phi(\alpha) - \tfrac{1}{3}\right) + \omega_2 \left(\tfrac{1}{8}\phi(\alpha) - \frac{2(\tan\alpha - \alpha)}{8\alpha^3} - \tfrac{1}{4}\right)\right]$$

$$= \frac{a}{P}\left[\omega_0 \alpha^2 \psi + 2\omega_1(\phi - 1) + \omega_2(2\phi - \tfrac{1}{2}\psi - \tfrac{3}{2})\right],$$

writing ϕ and ψ briefly for $\phi(\alpha)$ and $\psi(\alpha)$; since $m^2EI = P$, this may also be written

$$= \frac{a^3}{EI}\left[\frac{\omega_0}{4}\psi + \frac{2\omega_1(\phi - 1) + \omega_2(2\phi - \tfrac{1}{2}\psi - \tfrac{3}{2})}{4\alpha^2}\right]$$

but the first form, or the following form

$$\frac{a^3\omega_0}{4EI}\psi + \frac{a}{P}\left[2\omega_1(\phi - 1) + \omega_2(2\phi - \tfrac{1}{2}\psi - \tfrac{3}{2})\right]$$

would appear to be better for arithmetical work.

If desired, this may be put in terms of three particular values of w. But it is equally simple to find ω_0, ω_1 and ω_2 first from the three values and put them in. Thus if w_A, w_M and w_B are the values at A, $(x=0)$, M, $(x=a/2)$, and B, $(x=a)$, we have

$$\begin{aligned} w_A &= \omega_0 & & & \omega_0 &= w_A \\ w_M &= \omega_0 + \omega_1/2 + \omega_2/4 & \text{hence} & & \omega_1 &= 4w_M - w_B - 3w_A \\ w_B &= \omega_0 + \omega_1 + \omega_2 & & & \omega_2 &= 2w_B + 2w_A - 4w_M \end{aligned}$$

from which ω_0, ω_1, ω_2, may be calculated and substituted.

If the algebraic values be substituted, the expression becomes

$$\frac{a}{P}\left[w_A(3 + \alpha^2\psi - \psi - 2\phi) + w_M(2\psi - 2) + w_B(2\phi - \psi - 1)\right]$$

B (ii). When formal integration is not possible (or when laborious, for this possibly includes obtaining the polynomial or other form of w) two or more of the formulæ 4, 5, 6, 7 or 8 may be tried in the hope that sufficient accuracy is obtained; it may be remarked that a single evaluation of an integral by a numerical method is of dubious value, as nothing is known of the error. Failing such agreement, the simpler formulæ such as 4, 5 and 6 may be used two or more times for portions of the range; the variable distributed load may be replaced by a considerable number of equivalent concentrated loads and the summation formula used for these, checking the accuracy by an alternative replacement; this method is further referred to in the next section; or graphical integration may be used, plotting the product

$$w\left(\frac{\sin mX}{\sin ma} - \frac{X}{a}\right)$$

and measuring the area under the curve with a planimeter; this is likely, however, to be more laborious and less accurate than an arithmetical method.*

The coefficient of W for concentrated loads and of w in the integral for distributed loads, is

$$\frac{6}{P}\left(\frac{\sin mx}{\sin ma} - \frac{x}{a}\right) = \frac{a^2}{EI}\,\frac{6}{m^2a^2}\left(\frac{\sin mx}{\sin ma} - \frac{x}{a}\right).$$

Values of

$$\frac{6}{m^2a^2}\left(\frac{\sin mx}{\sin ma} - \frac{x}{a}\right)$$

for $r = x/a = 0,\ 0.5,\ 0.10 \ldots,\ 1.0$ and for various values of ma are given in the table herewith; intermediate values if required can be found from them by graphical interpolation, with sufficient accuracy for engineering purposes.

* Whittaker and Robinson, loc. cit., p. vi.

x/a \ Ma	0	0.5	1.0	1.5	2.0	2.2	2.4	2.5	2.6	2.7	2.8	2.9	3.0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
.05	.0490	.0514	.0564	.0670	.0897	.1063	.1325	.1520	.1789	.2180	.2805	.3952	.6725
.10	.0990	.1020	.1118	.1328	.1777	.2106	.2624	.3009	.3539	.4314	.5548	.7814	1.3294
.15	.1466	.1510	.1655	.1964	.2625	.3109	.3870	.4435	.5215	.6354	.8168	1.1497	1.9548
.20	.1920	.1976	.2166	.2567	.3424	.4052	.5038	.5770	.6780	.8255	1.0605	1.4916	2.5341
.25	.2344	.2412	.2641	.3125	.4159	.4915	.6103	.6986	.8201	.9977	1.2804	1.7992	3.0535
.30	.2730	.2809	.3072	.3628	.4814	.5682	.7044	.8054	.9446	1.1479	1.4716	2.0653	3.5005
.35	.3071	.3158	.3450	.4066	.5377	.6335	.7838	.8952	1.0487	1.2728	1.6295	2.2835	3.8645
.40	.3360	.3454	.3767	.4428	.5834	.6859	.8467	.9658	1.1298	1.3692	1.7502	2.4486	4.1364
.45	.3589	.3687	.4015	.4706	.6172	.7240	.8914	1.0153	1.1859	1.4348	1.8307	2.5563	4.3094
.50	.3750	.3850	.4185	.4889	.6381	.7467	.9165	1.0422	1.2152	1.4675	1.8687	2.6036	4.3789
.55	.3836	.3936	.4270	.4970	.6452	.7528	.9210	1.0454	1.2166	1.4660	1.8626	2.5888	4.3427
.60	.3840	.3937	.4261	.4941	.6375	.7415	.9040	1.0241	1.1891	1.4296	1.8118	2.5114	4.2006
.65	.3754	.3846	.4152	.4794	.6145	.7123	.8650	.9777	1.1326	1.3582	1.7165	2.3724	3.9552
.70	.3570	.3654	.3935	.4523	.5756	.6648	.8038	.9064	1.0473	1.2524	1.5780	2.1738	3.6112
.75	.3281	.3356	.3603	.4121	.5205	.5987	.7206	.8104	.9338	1.1133	1.3981	1.9190	3.1757
.80	.2880	.2942	.3150	.3583	.4489	.5142	.6158	.6906	.7933	.9426	1.1796	1.6128	2.6576
.85	.2359	.2407	.2569	.2906	.3609	.4115	.4901	.5480	.6274	.7429	.9260	1.2608	2.0679
.90	.1710	.1743	.1854	.2085	.2565	.2910	.3446	.3841	.4382	.5169	.6416	.8695	1.4190
.95	.0926	.0943	.1000	.1117	.1360	.1535	.1807	.2007	.2281	.2680	.3311	.4466	.7248
1.00	0	0	0	0	0	0	0	0	0	0	0	0	0

C. GENERAL.

(i) It may further be remarked that discontinuities in w in (A) or (B) are dealt with readily by dividing the integral at the points of discontinuity; the separate integrals may then be evaluated by formal or numerical methods as necessary or convenient.

An interesting and important application of this is to examine the error made in the right-hand side of the formula of the theorem by assuming a concentrated load W at b in place of a uniformly distributed load of the same amount spread from $b-d$ to $b+d$ (or conversely).

The contribution of the former (with no thrust) is

$$Wb\,(a^2-b^2)/aEI$$

and of the latter

$$\int_{b-d}^{b+d} wdX\,(a^2X-X^3)/aEI$$

where

$$2\,dw=W,\ i.e.,\ w\,(a^2X^2/2-X^4/4)\Big/_{b-d}^{b+d}EI=Wb\,(a^2-b^2-d^2)/aEI.$$

Thus the fractional error is $d^2/(a^2-b^2)$ and will be very small for small d except when b approximates to a; in the latter case, we note that $d \leqslant a-b$ to keep the equivalent distributed load in the bay; then $d^2/(a^2-b^2) \leqslant (a-b)/(a+b)$ and is small.

Thus, if a uniformly distributed load over one-fifth of the bay only, is replaced by a concentrated load of equal magnitude at its centre, the greatest error in the term in the three moment theorem is just over 5 per cent. If a uniform load over the whole bay be replaced in this way by five concentrated loads at $r=x/a=0.1$, 0.3, 0.5, 0.7 and 0.9, the separate errors are 1.01, 1.10, 1.33, 2.04 and 5.16 per cent., and the error over the whole is only 2.13 per cent. Replacing by ten concentrated loads, the error is 0.6 per cent. This suggests that with

variable distributed load it will usually suffice in engineering work to replace the distributed load by 5 or 10 equivalent concentrated loads.

(ii) Variation of w is also dealt with by definite integral forms in Phil. Mag., Ser. 7, XXVII, p. 328 (1939) when there is no thrust but there is variation of I across the bay, in the form

$$I_x = I_A/(1 + \sum_{n=1}^{n=8} K_n x^n/a^n).$$

This may be used to give results approximately true even when the actual variation in I is by finite increments.

NOTE ON BIOT'S DYNAMIC MODULUS.

By W. J. Duncan, D.Sc., A.M.I.Mech.E., F.R.Ae.S.*

§1. Introduction and Summary.

In reference 1 Biot has given a simple and valuable formula for what he calls the "dynamic modulus" of a flywheel system or airscrew in terms of resonance and anti-resonance frequencies. The resonance frequencies are the natural frequencies when the systems are free, and the anti-resonance frequencies are the natural frequencies when the end of the flywheel shaft (or the airscrew boss) is fixed. The dynamic modulus is defined to be the ratio of the amplitude of the applied periodic couple to the amplitude of the angular movement produced at the point of application, and is a function of the frequency of the periodic couple. A very useful application of the dynamic modulus can be made to engine-propeller systems, for the natural frequencies of the combination are such that the dynamic moduli of the two components are equal and opposite. Hence the natural frequencies of the system can be found when the dynamic moduli of the components as functions of frequency are known. This treatment of the engine-airscrew system is given by Carter in reference 2. Carter makes use of diagrams in which the dynamic flexibility or admittance is plotted against frequency. The admittance is the reciprocal of Biot's dynamic modulus. A principal merit of Biot's formula is that it permits the determination of the dynamic modulus from quantities which are easier to determine experimentally than the modulus itself.

In the present note a general investigation of the dynamic modulus of undamped systems is given, and simple general formulæ are derived. The modulus is defined in general to be the ratio of the amplitude of a generalised force, say, Q_1 to the amplitude q_1 of the *corresponding* generalised co-ordinate when all the other generalised forces are zero.† Certain dynamic coefficients are zero for flywheel and propeller systems of the type considered by Biot, and then the general formulæ reduce to those given by him.

§2. General Formulæ for the "Dynamic Modulus."

The treatment to be given applies to systems having any number n of degrees of freedom, but for simplicity the case $n=3$ will be considered in detail. The equations of motion of the system are linear with constant coefficients, and damping terms are absent.‡ Let the generalised co-ordinates adopted be q_1, q_2, q_3, and the corresponding generalised forces Q_1, Q_2, Q_3. Then the Lagrangian equations of motion may be written

$$a_{11}\ddot{q}_1+c_{11}q_1+a_{12}\ddot{q}_2+c_{12}q_2+a_{13}\ddot{q}_3+c_{13}q_3=Q_1 \quad . \quad . \quad (2.1)$$

$$a_{21}\ddot{q}_1+c_{21}q_1+a_{22}\ddot{q}_2+c_{22}q_2+a_{23}\ddot{q}_3+c_{23}q_3=Q_2 \quad . \quad . \quad (2.2)$$

$$a_{31}\ddot{q}_1+c_{31}q_1+a_{32}\ddot{q}_2+c_{32}q_2+a_{33}\ddot{q}_3+c_{33}q_3=Q_3 \quad . \quad . \quad (2.3)$$

where the coefficients a are the inertias and the coefficients c are the stiffnesses. Now let Q_1 be a force proportional to $\sin \omega t$, while the other generalised forces are zero. If attention be confined to the steady forced motion proportional to

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† The amplitude is that of the steady motion having the same frequency as that of the applied force.

‡ It is easy to generalise the treatment to cases where damping terms are present, but the results do not appear to have much utility.

$\sin \omega t$, and if Q_1, q_1, q_2, q_3 are now amplitudes, then the equations of motion yield

$$(c_{11}-a_{11}\omega^2)\,q_1+(c_{12}-a_{12}\omega^2)\,q_2+(c_{13}-a_{13}\omega^2)\,q_3=Q_1 \quad . \quad . \quad (2.4)$$

$$(c_{21}-a_{21}\omega^2)\,q_1+(c_{22}-a_{22}\omega^2)\,q_2+(c_{23}-a_{23}\omega^2)\,q_3=0 \quad . \quad . \quad (2.5)$$

$$(c_{31}-a_{31}\omega^2)\,q_1+(c_{32}-a_{32}\omega^2)\,q_2+(c_{33}-a_{33}\omega^2)\,q_3=0 \quad . \quad . \quad (2.6)$$

Solution of these equations in the ordinary way yields the following expression for the dynamic modulus

$$\mu_d=\frac{Q_1}{q_1}=\frac{\Delta\,(\omega^2)}{\Delta_1\,(\omega^2)} \quad . \quad . \quad . \quad . \quad . \quad (2.7)$$

where

$$\Delta\,(\omega^2)\equiv\begin{vmatrix} c_{11}-a_{11}\omega^2 & c_{12}-a_{12}\omega^2 & c_{13}-a_{13}\omega^2 \\ c_{21}-a_{21}\omega^2 & c_{22}-a_{22}\omega^2 & c_{23}-a_{23}\omega^2 \\ c_{31}-a_{31}\omega^2 & c_{32}-a_{32}\omega^2 & c_{33}-a_{33}\omega^2 \end{vmatrix} \quad . \quad . \quad (2.8)$$

is the frequency determinant of the system and

$$\Delta_1\,(\omega^2)\equiv\begin{vmatrix} c_{22}-a_{22}\omega^2 & c_{23}-a_{23}\omega^2 \\ c_{32}-a_{32}\omega^2 & c_{33}-a_{33}\omega^2 \end{vmatrix} \quad . \quad . \quad . \quad (2.9)$$

is the frequency determinant of the system so constrained that q_1 is kept constantly zero. Let the expanded form of (2.8) be

$$\Delta\,(\omega^2)\equiv p_0\omega^6+p_1\omega^4+p_2\omega^2+p_3, \quad . \quad . \quad . \quad . \quad (2.10)$$

and let the roots of $\Delta\,(\omega^2)=0$ be ${\omega_1}^2$, ${\omega_2}^2$, ${\omega_3}^2$. Explicitly

$$p_0=-|\,a\,|, \quad . \quad . \quad . \quad . \quad . \quad (2.11)$$

$$p_3=\;\;|\,c\,|, \quad . \quad . \quad . \quad . \quad . \quad (2.12)$$

while the values of the other coefficients are not required.* Then

$$\Delta\,(\omega^2)\equiv-|\,a\,|\,(\omega^2-{\omega_1}^2)\,(\omega^2-{\omega_2}^2)\,(\omega^2-{\omega_3}^2). \quad . \quad . \quad (2.13)$$

Similarly

$$\Delta_1\,(\omega^2)\equiv\begin{vmatrix} a_{22}a_{23} \\ a_{32}a_{33} \end{vmatrix}(\omega^2-{}^*\omega_1{}^2)\,(\omega^2-{}^*\omega_2{}^2), \quad . \quad . \quad (2.14)$$

where ${}^*\omega_1{}^2$ and ${}^*\omega_2{}^2$ are the roots of $\Delta_1\,(\omega^2)=0$. Hence equation (2.7) becomes

$$\mu_d=-\frac{|\,a\,|\,(\omega^2-{\omega_1}^2)\,(\omega^2-{\omega_2}^2)\,(\omega^2-{\omega_3}^2)}{\begin{vmatrix} a_{22}a_{23} \\ a_{32}a_{33} \end{vmatrix}(\omega^2-{}^*\omega_1{}^2)\,(\omega^2-{}^*\omega_2{}^2)}. \quad . \quad . \quad . \quad (2.15)$$

It follows from equations (2.10) to (2.13) that

$$|\,a\,|=\frac{|\,c\,|}{{\omega_1}^2{\omega_2}^2{\omega_3}^2}. \quad . \quad . \quad . \quad . \quad . \quad (2.16)$$

Similarly

$$\begin{vmatrix} a_{22}a_{23} \\ a_{32}a_{33} \end{vmatrix}=\frac{\begin{vmatrix} c_{22}c_{23} \\ c_{32}c_{33} \end{vmatrix}}{{}^*\omega_1{}^2{}^*\omega_2{}^2}. \quad . \quad . \quad . \quad . \quad . \quad (2.17)$$

By substitution (2.15) becomes

$$\mu_d=\frac{|\,c\,|\left(1-\frac{\omega^2}{{\omega_1}^2}\right)\left(1-\frac{\omega^2}{{\omega_2}^2}\right)\left(1-\frac{\omega^2}{{\omega_3}^2}\right)}{\begin{vmatrix} c_{22}c_{23} \\ c_{32}c_{33} \end{vmatrix}\left(1-\frac{\omega^2}{{}^*\omega_1{}^2}\right)\left(1-\frac{\omega^2}{{}^*\omega_2{}^2}\right)}. \quad . \quad . \quad . \quad (2.18)$$

When ω is vanishingly small this yields the static value of the modulus, namely,

$$\mu_s=\frac{|\,c\,|}{\begin{vmatrix} c_{22}c_{23} \\ c_{32}c_{33} \end{vmatrix}}, \quad . \quad . \quad . \quad . \quad . \quad (2.19)$$

which is immediately deducible from equations (2.4) to (2.6) with ω made zero.

* $|a|$ is a compact way of writing the determinant of the coefficients a.

§3. An Important Special Case.

Suppose that there is no direct stiffness appropriate to the co-ordinate q_1, and that this co-ordinate is not elastically coupled to the other co-ordinates, *i.e.*, suppose that

$$c_{11}=c_{12}=c_{21}=c_{13}=c_{31}=0. \quad . \quad . \quad . \quad . \quad (3.1)$$

Then, as will be shown, the formula for the dynamic modulus can be reduced to a particularly simple form which has valuable practical applications. Before the proof is given a concrete example of the type of system considered will be mentioned. A dynamical system is mounted on an axle which is capable of rotating in fixed bearings and the system is otherwise unconnected with the fixed base. If the angle of rotation of the axle is q_1, then all the stiffness coefficients having a suffix 1 are zero as postulated.

Direct solution of equations (2.4) to (2.6) gives in the present case

$$\mu_d=\frac{Q_1}{q_1}=\frac{-\omega^2\begin{vmatrix} a_{11} & -a_{12}\omega^2 & -a_{13}\omega^2 \\ a_{21} & c_{22}-a_{22}\omega^2 & c_{23}-a_{23}\omega^2 \\ a_{31} & c_{32}-a_{32}\omega^2 & c_{33}-a_{33}\omega^2 \end{vmatrix}}{\begin{vmatrix} c_{22}-a_{22}\omega^2 & c_{23}-a_{23}\omega^2 \\ c_{32}-a_{32}\omega^2 & c_{33}-a_{33}\omega^2 \end{vmatrix}} \quad . \quad . \quad . \quad (3.2)$$

Hence when ω tends to zero

$$\frac{\mu_d}{\omega^2}=\frac{-a_{11}\begin{vmatrix} c_{22} & c_{23} \\ c_{32} & c_{33} \end{vmatrix}}{\begin{vmatrix} c_{22} & c_{23} \\ c_{32} & c_{33} \end{vmatrix}}=-a_{11}. \quad . \quad . \quad . \quad . \quad (3.3)$$

Since $|c|=p_3$ is zero, one of the roots of $\Delta(\omega^2)$ vanishes, say ω_3. Hence equation (2.15) gives

$$\frac{\mu_d}{\omega^2}=-\frac{|a|\omega_1^2\omega_2^2\left(1-\frac{\omega^2}{\omega_1^2}\right)\left(1-\frac{\omega^2}{\omega_2^2}\right)}{\begin{vmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \end{vmatrix}*\omega_1^2*\omega_2^2\left(1-\frac{\omega^2}{*\omega_1^2}\right)\left(1-\frac{\omega^2}{*\omega_2^2}\right)} \quad . \quad . \quad (3.4)$$

When ω tends to zero this gives

$$\frac{\mu_d}{\omega^2}=-\frac{|a|\omega_1^2\omega_2^2}{\begin{vmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \end{vmatrix}*\omega_1^2*\omega_2^2}$$

$$=-a_{11} \text{ by (3.3).}$$

Hence (3.4) reduces to

$$\mu_d=\frac{-a_{11}\omega^2\left(1-\frac{\omega^2}{\omega_1^2}\right)\left(1-\frac{\omega^2}{\omega_2^2}\right)}{\left(1-\frac{\omega^2}{*\omega_1^2}\right)\left(1-\frac{\omega^2}{*\omega_2^2}\right)}. \quad . \quad . \quad . \quad (3.5)$$

which is equivalent to Biot's formula.* It will be seen that μ_d can be calculated for any frequency when the inertia coefficient a_{11} and the four natural frequencies have been determined.

List of References.

1. Biot, M. A. "Coupled Oscillations of Aircraft Engine-Propeller Systems." Journal of Aeronautical Sciences, Vol. 7, No. 9, July, 1940.
2. Carter, B. C. "The Vibration of Airscrew Blades with particular reference to their Response to Harmonic Torque Impulses in the Drive." R. & M. 1758, July, 1936.

* Mr. J. F. Shannon has pointed out that a formula very similar to Biot's for the reactance of electrical systems has been known for some time. The formula was stated without proof by G. A. Campbell in the "Bell System Technical Journal" for November, 1922. A proof was given by R. M. Foster in the April 1924 issue of the same journal. Reference may also be made to Starr "Electric Circuits and Wave Filters" (Pitman, 1938), p. 164.

REVIEWS.

AIRCRAFT ENGINES (Volume II).

A. W. Judge, A.R.C.S., A.F.R.Ae.S. Chapman and Hall. 1941. 30/- net.

Volume I of "Aircraft Engines," published some months ago, was mainly concerned with the theoretical and experimental aspects of aircraft engines. The volume under review is largely descriptive, though certain design and theoretical considerations are touched upon.

Mr. Judge has been handicapped by war conditions; nevertheless, he has given in these two volumes a mine of information of value to the aero engine designer and all those concerned in any way with aircraft engines. The first two chapters give a summing up of general design considerations and torque and balance considerations.

Chapter III is concerned with types of aircraft engines, beginning with the Wright Brothers four-cylinder in-line vertical water-cooled engine weighing about 16 lbs. per h.p. and ending with the modern Merlin. The radial air-cooled engine forms the subject matter of Chapter IV, and sleeve valve aircraft engines of Chapter V. The remarkable development work of the Bristol Aeroplane Company on the sleeve valve engine occupies, and deservedly so, a considerable part of this chapter. In Chapter VI there is a description of various other types of aircraft engines, beginning with the two-cycle engine and the compression ignition engine, both of which hold out considerable possibilities not yet fully exploited. It is a pity that the Bristol Company were not able to continue the Phœnix in 1934. Such an engine now would have shed most of its teething troubles and been of immense value on long range work and for its greater ease of maintenance and freedom from the troubles of the carburettor engine.

Chapter VII deals with aircraft engine components, cylinders, crankcases, pistons, connecting rods, crankshafts, valves and gears. In the following chapter lubrication is dealt with, and is followed by an important chapter on the ignition system. Aero engines have to operate under much more severe conditions than any other type of internal combustion engine, and both these chapters bring out clearly how great these difficulties are and how they have been, to a great extent, overcome. The height of success, indeed, with the aero engine designer, is literally the greatest height at which he can make his engine work successfully and reliably.

The book ends with chapters on the exhaust system, accessories and testing.

This is a practical book and it is of interest, in view of the criticisms occasionally made against the high-brow nature of the Society's lectures, to note in the list of references the number made to the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY. Some twelve per cent. of the references are to the Journal.

THE PRACTICAL APPLICATION OF ALUMINIUM BRONZE.

C. H. Meigh. McGraw-Hill Publishing Co., Ltd. 1941.

Aluminium bronzes consist of copper alloyed with aluminium, an alloy of copper, manganese and aluminium, or alloys of these three metals with nickel

or iron. The outstanding advantage of aluminium bronze is its high tensile strength. The strength weight ratio, as cast, is indeed only below that of heat-treated elektron and heat-treated Y alloy. The ratios are, respectively, 147, 199 and 176. These alloys are highly resistant to corrosion, and are easily machined. The ultimate tensile strength of aluminium bronze in its cast form is 40 tons per sq. inch, its elongation per cent. on 2 in. 20, and its weight per cubic inch 0.2725 lbs. Young's modulus is 14.5 to 19 times 10^6, as against 6.5×10^6 for cast elektron.

In a list of uses given by the author for the alloy, there is no mention or suggestion of any aeronautical use. That is a little odd.

In the search for materials for aircraft and also engine construction, especially for substitutes for existing materials, many qualities have to be taken into consideration before any material is accepted.

This is a practical statement of properties for the engineer. That the alloys have not been used more extensively in engineering has been largely due to ignorance of the correct foundry technique. Now the handicap is being rapidly overcome, alloys with properties possessed by the aluminium bronze must come into wider use steadily.

The author of this survey is both an expert in the laboratory and the foundry and the work which he has carried out for so many years on the aluminium bronzes is of the highest importance. In the book under review the results obtained and the practical applications are set forth clearly for the practical engineer, and the practical engineer would be well advised to study this book with care. He will be well repaid.

THE RIGGING, MAINTENANCE, AND INSPECTION OF AIRCRAFT ("A" LICENCE).

W. J. C. Speller. Sir Isaac Pitman and Sons, Ltd. 1941. 5/- net.

This is the second and revised edition of a work which has been reprinted five times since it was first published in 1934. Much of the material remains standard, but there is much which is necessarily new since the first date of publication. It is now necessary for a ground engineer to have a knowledge of fire fighting equipment and its installation tests requirements, and a section has been added to Chapter II on this equipment.

Chapter III is entirely new on Hydraulic equipment affecting the safety of aircraft. The importance of this equipment is increasing rapidly with increasing sizes and speeds of aircraft, and it is a very necessary part of a ground engineer's knowledge to understand thoroughly how the hydraulic equipment works. The author succeeds in explaining simply the installations upon which the life of the pilot may depend.

Another new chapter is that on Instruments: Methods of inspecting and testing the installation. This chapter deals with airspeed indicators, altimeters, turn indicators and compass installations.

This is an excellent 5/- worth and can be thoroughly recommended.

JANE'S ALL THE WORLD'S AIRCRAFT.

Compiled and edited by C. G. Grey and Leonard Bridgman. Sampson, Low. 1940. Three guineas net.

A. P. Herbert once wrote a poem, entitled "Plain Jane." Some one ought to do a like service for aviation, only, of course, his poem would be entitled "Plane Jane," on this her thirtieth birthday. In contradistinction to most

things the older she gets the better she gets, and the thirtieth issue of Jane definitely keeps up the improvement shown year after year under C. G. Grey's knowledgeable and competent editorship.

The Royal Aeronautical Society is in the fortunate position of possessing a complete set of Jane from the first issue in 1911. Here is the history of the development of the world's aircraft and aircraft engines since 1911 in a form which exists nowhere else. C. G. Grey's annual review is such that it should enable any aeronautical writer to keep clear of the major mistakes made so often in the non-technical press.

One would like to quote from the 1911 and 1940 issues. In 1911 common speeds were 45-50 m.p.h., horse-powers 40 to 60, and range 75-150 miles.

In 1940 common speeds are 250-300 m.p.h., horse-powers 1,000-1,200, and ranges 1,200 to 1,800 miles.

" All the World's Aircraft " has reached that position when detailed criticism is a matter of choice for the reviewer, and not one of saying whether the volume under review is worth buying or not. Jane is a necessary part of the equipment of all aviation offices. Those who dislike the editorship review on the principle that though they believe, as Lieut.-Colonel Moore-Brabazon once said, most things they read in black and white, they don't necessarily believe what they read in Grey. Those who like the editorship review differently. But Jane under any other name would sell in Fleet Street or anywhere else on its well-deserved reputation only. The 1940 edition has weathered the storm of war most successfully, and though battered a little by the heavy guns of censorship, it has arrived in port safe and sound, with most of its valuable cargo released for aeronautical consumption.

METAL AIRCRAFT CONSTRUCTION.

M. Langley, F.R.Ae.S., A.M.I.N.A. Sir Isaac Pitman and Sons, Ltd. 1941. 4th Edition. 15/- net.

This is the fourth and revised edition of Langley's book which was first published in 1932, a somewhat slim child. Nine years later the child has grown up into a very healthy youth and it has certainly developed along the lines of high hope which its progenitor had for it in its early days.

Langley on " Metal Construction " has rapidly taken its place as one of the books to be recommended. Like all technical books now being published the author has had to pass through the cleansing fires of censorship, but it is not doubted that when the war is over that the charred pages will rise again from the ashes and Langley will be in greater demand than ever.

A very considerable amount of matter has been added to this new edition and much of the text rewritten to bring it up-to-date. The author has been able to draw upon details of construction of British and American aircraft which were not available when the third edition was published. The advance in construction during these last few years has been impressive. With the constant increase in size the aeroplane is rapidly taking its place as a true engineering structure. There are many who will dispute that statement, saying that it is an engineering structure already. In one sense, of course, that is vitally true, but the never ending struggle to save weight has introduced certain elements of construction which would not be admitted by what may be called the heavy weight engineers.

It is unfortunate that so many things are kept secret nowadays, so secret, indeed, that probably everybody in the aircraft world knows all about them except the unfortunate aircraft designer. When the war is over, however, it is to be hoped that the publishers will persuade Mr. Langley to bring out a

newer edition still, so that those who have been engaged in designing will have a chance to see as a whole what great strides they have made. It is certain that a new edition will be necessary and one is confident that its standard will be as high as the present edition.

PRACTICAL SOLUTION OF TORSIONAL VIBRATION PROBLEMS.

W. Ker Wilson, Ph.D., M.Sc., M.I.Mech.E. Two volumes. Chapman and Hall. Vol. 1, 1940, 42/-; Vol. 2, 1941, 42/-.

These two volumes are second editions of a work first published in 1935 in one volume. That a second edition should be called for in such a comparatively brief period of time, and that this second edition should be nearly three times the length of the first, show the outstanding and increasing importance of problems on torsional vibration which are now facing the engineer.

A very considerable amount of the original text has been rewritten to bring the two volumes up-to-date and new chapters added. The following are briefly the more important changes.

More comprehensive treatment of flexible couplings, including the use of rubber as a structural material, with special reference to rubber-in-shear couplings.

The addition of material relating to the choice of crank sequence and firing order of various engine aggregates, including single and multi-row radial engines with articulated connecting rods, and Vee type in-line engines.

General systems, including the treatment of geared engines supported on flexible mountings.

Vibration measuring instruments, with a full discussion of instrument theory and vibration.

The subject matter relating to engine damping has been completely revised; and a comprehensive treatment given of the properties and materials used in transmission systems, including a study of fatigue phenomena, with special reference to the influence of discontinuities in causing stress concentrations.

A simple practical treatment of airscrew blade vibration and its influence on the vibration characteristics of aircraft power plants.

A detailed review of the 1,400 pages of these two volumes cannot be given in the space allotted to the reviewer, and attention can only be drawn to the high-lights of a work which is monumental in its scope and invaluable in its subject matter. Both volumes contain numerous worked out examples on aero engine and airscrew problems, examples which add immensely to the value of the text.

The chapter headings are as follows:—Vol. 1, Chapter I, Torsional Vibration; Chapter II, Natural Frequency Calculations; Chapter III, Equivalent Oscillating Systems; Chapter IV, Flexible Couplings; Chapter V, Geared Systems; Chapter VI, Determination of Stress due to Torsional Vibration at Non-resonant Speeds. Vol. 2, Chapter VII, Determination of Stresses due to Torsional Vibration at Resonant Speeds; Chapter VIII, Measurement of Torsional Vibration Amplitudes and Stresses; Chapter IX, Analysis of Torsiograph Records; Chapter X, Torsional Vibration Damping Devices; Chapter XI, Rotating Pendulum Vibration Absorbers; Chapter XII, Dynamic Characteristics of Electrical Generating Sets Direct-Coupled to Internal Combustion Engines and Flywheel calculations for Marine Installations.

There is an appendix to Volume I on effective inertia method of torsional vibration analysis with special reference to aero engine airscrew systems, and one to Volume 2 on harmonic analysis.

This brief summary of the contents of two volumes gives a clear indication of their wide scope, though it does scant justice to the most excellent exposition by the author of his subject.

The last few years, particularly the last ten years, has brought into prominence so many new problems in aircraft engine and propeller design, consequent on high powers and higher speeds, that the book under review becomes a necessary part of the equipment of all those concerned with engine and airscrew design. Here they will find the practical solution of their problems in terms and by methods the engineer and mathematicians will understand.

Dr. Ker Wilson is to be congratulated without reserve on the production of a practical textbook of very high value. The publishers deserve praise for their excellent presentation of Dr. Wilson's work. Illustrations and setting up of text may mar the best work of any author. In these two volumes one can say without reserve that the collaboration between author and publisher has been all that could be desired, and that high as the price of the two volumes is, no one will begrudge the price paid for the value they will receive.

DEFEATING THE BOMBER.

H. E. Wimperis, C.B., C.B.E. J. M. Dent and Sons, Ltd. 1941. 1/- net.

This is the fourth of the Liberty Handbooks now being published by J. M. Dent and Sons, and excellent handbooks they are.

The author of "Defeating the Bomber" has been very much concerned with the development of all types of aircraft, civil and military. He has watched them grow up, and go up, from aircraft of less than a quarter of a ton in weight able to climb to a mile above the earth, to aircraft weighing up to thirty tons and able to climb out of sight, though not always out of mind. For twelve years, as Director of Scientific Research at the Air Ministry, Mr. Wimperis provided the necessary scientific nourishment which enabled this growth to be made. He saw the fighter and the bomber through many of their teething troubles, well aware, however, that only civil aircraft will ever grow wisdom teeth.

For just on a quarter of a century, too, the author has been a member of the Royal Aeronautical Society, during many of which years he served on the Council, and for two of which he served as President. By these contacts, and as a member of the Aeronautical Research Committee and many other technical aeronautical committees, the author has acquired a knowledge of aircraft development, and an insight into its possible future, which enables him to speak with high authority.

This book will prove a most excellent corrective to the soothing syrup of self-satisfied speakers and the welter of wishful writing which has bemused the public into thinking the solution of the bomber problem is in sight.

Mr. Wimperis rightly lays stress upon the difficulties which have to be faced, and discusses many of the solutions which have been put forward and shows why they are not practicable. "The primary defence against the bomber is the interceptor fighter" he remarks, and that will always be true. The real problem, of course, is to find the bomber, especially at night, and the author shows how difficult that may be. He makes it clear that every method which has in it the gleam of a hope of success, is tried out fully. The defence against the night bomber is not a matter of one thing alone. The night fighter, the anti-aircraft gun, the balloon barrage, the listening-in post and wireless, all play their part, all developing a better technique as the war lengthens. An increasing toll of the night bomber may act as a deterrent, but that toll must be far heavier than it is now to prevent the attempt being made to get through. The reviewer does not intend to leave the impression that the outlook is hopeless however.

"We have thought it worth while to indicate some of the difficulties which need to be overcome," writes Mr. Wimperis. ". . . Experts are hopeful about the way some of the new developments are going. If we were at liberty to describe these, the public would be enthralled and vastly encouraged."

The author ends his book with a chapter on "Is outlawry possible?" The Disarmament Conference of 1932-34 nearly solved that problem. The conference after the war will get nearer to its solution, but it will take a conference after the last war to end wars to make it a *fait accompli*.

ELEMENTARY MATHEMATICS FOR WIRELESS OPERATORS.

W. E. Crook, A.M.I.E.E., A.F.R.Ae.S. Sir Isaac Pitman and Sons, Ltd. 1941. 3/6 net.

Mathematics is certainly coming into its own. Many textbooks are now available on the subject as applied to engineering and other branches of science, and this is as it should be, for mathematics on its own is far too wide for anyone except the full blown mathematician to tackle.

The danger of all specialist books, however, is that in the attempt to provide the information necessary to do the job something may be omitted which may lead to trouble later on. A little learning is a dangerous thing, and a little mathematics may be even more dangerous to those who attempt to apply their elementary knowledge by an ingenious method of extrapolation to problems demanding more than simple formulæ.

Mr. Crook aims at explaining arithmetic, algebra, geometry and trigonometry, graphs and mechanics quickly and simply, so that they can be used by the wireless operator with confidence. His book is useful in that it will help many wireless operators over the mathematical stile, but it suffers from precisely the remark made above, that a little learning may be a dangerous thing.

As an example, in explaining the elementary signs of arithmetic and algebra what happens when two quantities are multiplied or divided, when they have opposite signs is not stated. The rule, in fact, could only be deduced from the examples given.

For those who are being taught the necessary mathematics, and who will have the possible pitfalls explained to them, the book can be recommended, however, as a useful introduction. The author assumes that most wireless operators are frightened of mathematics, and he has succeeded in this book in showing that there is nothing of which they need be afraid. The book is written in a colloquial style which will appeal to those who ask the question in Mr. Crook's preface, "Why should I bother about anything so repulsively dull as mathematics?"

MATHEMATICAL METHODS IN ENGINEERING. AN INTRODUCTION TO THE MATHEMATICAL TREATMENT OF ENGINEERING PROBLEMS.

T. von Karman and M. A. Biot. McGraw, Hill Publishing Co. 1940. 28/-.

The names of von Karman and M. A. Biot separately command respect. Together they command attention.

In every branch of engineering there is a greater demand than ever for a sound knowledge of mathematics. The complexity of modern engineering, indeed, is lessening every year the gap which was once so wide between the engineer and the mathematician. There are many engineers who manage to face up to and solve their individual problems with an astonishingly small amount of mathematics, but they are engineers who are dealing with problems which are comparatively simple and whose fundamental difficulties have been solved for them in engineering textbooks.

The authors, in their preface, rightly point out, however, that the mathematics as taught for engineers nowadays is usually adequate, but what is lacking is a better understanding of the potentialities of its application.

A knowledge of simple calculus, analytical geometry and algebra is all that the authors assume for the intelligent understanding of their book.

Chapter I is an introduction to linear differential equations and their solutions and is followed by a chapter on Bessel functions. It is refreshing to read the heading to this chapter, which says about Bessel, " Fondness for figures and a distaste for Latin grammar led him to the choice of a mercantile career. . . . Encouraged by Olbers, Bessel turned his back to the prospect of affluence, chose poverty and the stars."

Bessel functions play an important part in the solution of many engineering problems. The analogies of Bessel functions to elementary exponential and trignometric functions should make the understanding of this chapter easy to the engineer, who has hitherto dodged Bessel functions as something essentially belonging to the mathematical world.

The fundamental concepts of dynamics forms the subject matter of Chapter III, beginning with Newton's Laws of Motion. Attention is paid in this chapter to gyroscopic motion, the methods of virtual displacements and d'Alembert's principle and Lagrange's equations. In the set of problems at the end of this chapter the immediate application of the preceding text to engineering problems is evident to aircraft engineers as well as students in other branches of engineering. The reviewer was taken back to his early days of struggling for a degree when he noted that the first problem at the end of this chapter is the famous problem of the monkey and the weight, a problem the solution of which still remains a matter of argument among present day students.

Chapter IV deals with some elementary problems in dynamics, those problems which require the integration of differential equations with given initial conditions. A brief, but necessary, survey of elliptic integrals and functions is given. Here are given solutions of the motion of a particle under the action of gravity and air resistance, the problem of the bomb and the shell, and the equations of motion of the aeroplane. In discussing the latter problem the authors acknowledge to Lanchester's book, " Aerodynamics," published in 1908.

Chapter V has direct applications for the aero engine designer, dealing as it does with small oscillations of conservative systems. The following chapter on small oscillations of non-conservative systems discovers as its first example the elementary theory of wing flutter and in a later section the longitudinal stability of an aeroplane.

A number of problems of interest and importance to the aircraft engineer are dealt with in Chapter VII, under the title of the differential equations of the theory of structures. The general theory of the bending of beams, vibration of beams (the initial speed of a rotating shaft), the buckling of struts, and beams with combined lateral and end loads form the chief subject matter of this chapter. It is logically followed by chapters on the application of Fourier series to structural problems, and periodic processes occurring in mechanical and electrical systems.

The last chapter covers the ground of equations of finite differences as applied to engineering. The aeronautical engineer will find illuminating sections on the application of the methods of finite differences to continuous beams, the buckling of a lattice truss, and the initial speeds of a multi-cylinder engine.

" Mathematical Methods in Engineering " concludes with a number of pages, entitled " Words and Phrases," " an attempt to give the strictly mathematical definitions of some of the concepts and operations commonly used by physicists and engineers," to quote. Appropriately this most excellent finish to a first-class book begins with the quotation: " God made the integers; all the rest is the work of man."

This is a book which can be most heartily recommended to all those engineers who are concerned with the increasing complexity of modern engineering pro-

blems. It provides a modern bridge between the engineer and the mathematician, a bridge on which there should be a heavy two-way traffic.

AERONAUTICS IN THE UNION AND CONFEDERATE ARMIES, WITH A SURVEY OF MILITARY AERONAUTICS PRIOR TO 1861.

F. Stansbury Haydon. Volume I. The John Hopkins Press, Baltimore. 1941. $4.00. (Oxford University Press.)

It is a long flight from the time with which this book deals and the present day. In 1861 experiments were made with fixed observation balloons at a height of a few hundred feet to obtain a wider reconnaissance of the enemy's movements. In 1941 aircraft flying at heights of six miles and at speeds of 300 miles per hour or more are doing the same work.

It may seem a little out of date to produce such a work as the one under review at the present time, but the reviewer feels that this is just the kind of book which should appear now as an antidote to the fierce movement and still fiercer sensationalism of modern civilisation. There is something to be said for the quiet backwaters of a bygone age when peacefully flowing rivers did not serve as a guide to high speed bombers. The reviewer sleeps near one such peaceful river with a noisy night sky above him, so writes with feeling.

After a brief survey of military aeronautics prior to 1861, the rest of the book is concerned with its main title. The author quotes from André Giraud de Vilette, who ascended in a balloon with Pilâtre de Rozier in October, 1783. In that month Vilette wrote to the *Journal de Paris* about his ascents and remarked, "From this moment I was convinced that this apparatus, costing but little, could be made very useful to an army for discovering the positions of its enemy, his movements, his advances, and his dispositions, and that this information could be conveyed to the troops operating the machine."

Although in England and on the Continent the use of balloons for military purposes was discussed at length, it was not until the Civil War that its possibilities were looked at in America. In 1840 Colonel Sherburne suggested the employment of balloons for observation against the Indians in Florida, a suggestion which did not mature.

In 1846 John Wise, a well known aeronaut, proposed the capture of the fortress of San Juan de Ulna, near Vera Cruz, by using a balloon carrying 18,000 pounds of "percussion torpedoes and shells." He suggested anchoring the balloon a mile above the fortress and bombing it into submission. The war department ignored Wise's suggestion and Vera Cruz was captured by other means.

In 1861 the Civil War broke out. The value of the balloon for reconnaissance purposes was pressed upon the authorities on both sides of the conflict, by well known American aeronauts, James Allen, John Wise, John La Mountain and T. S. C. Lowe. The work of the first two was not successful, but both Mountain and Lowe demonstrated the value of the military balloon. Mountain, a difficult personality, was ultimately superseded by Lowe, an account of whose work occupies more than half the book.

It is not proposed here to give in any detail an account of the trials and troubles of military ballooning of those far off days. It is a story, however, which reveals the astonishing inability of army commanders to visualise the possibilities of any new form of warfare. This is no reflection upon the army commanders of any particular country. All military authorities, all our forces, have shown at one time or another, that lack of imagination which has delayed the use and development of a new weapon for years.

The author has written not only a most full and interesting account of the use of balloons in the Civil War, but he has documented his account in the most

thorough and painstaking manner. Hardly a statement is made throughout but its original source is given.

Of the many illustrations, the aerial sketch map of Sewall's Point, Virginia, made in August, 1861, from a height of 3,500 feet by La Mountain, and a panoramic sketch of Confederate batteries and camps on the Lower Potomac, drawn by Colonel Small in December, 1861, are the most significant of progress to come.

THE ROYAL AERONAUTICAL SOCIETY
WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES.

JULY, 1941.

Election of President and Vice-Presidents.

At a Council Meeting of the Royal Aeronautical Society held in June, 1941, Mr. Griffith Brewer, Hon.F.R.Ae.S., was elected President of the Society for the year October, 1941—September, 1942.

The following were elected Vice-Presidents for the same period:—

Professor L. Bairstow, C.B.E., F.R.S., F.R.Ae.S.
Mr. W. C. Devereux, F.R.Ae.S.
Lt.-Col. The Rt. Hon. J. T. C. Moore-Brabazon, M.C., F.R.Ae.S., M.P.

Discussions.

The Council have decided that, in spite of the difficulties of war conditions, an endeavour should be made to maintain active interest in technical aeronautics among the entire membership of the Society. It is intended to hold discussions on some or all of the following subjects in the near future. Members of the Society are invited to inform the Secretary which discussion or discussions they would like to attend. It is proposed to hold the discussions on Sundays at the most suitable place in London or the country, depending upon the replies received. Discussions will only be held on those subjects, which, from the replies received, are shown to be of interest to a number of members.

These discussions will be open to all grades of the Society and, to satisfy the needs of security and safety, it will be necessary for those who wish to attend any particular meeting, to notify the Secretary as quickly as possible, so that arrangements can be made for the exact date and place of the meeting.

It must clearly be understood that no one will be allowed to attend the meeting who has not notified the Secretary in advance, and no notice will be given in the Journal of the time or place of the meeting.

When a discussion has been arranged, members who have indicated their interest in that particular discussion will be notified.

The following is a list of proposed subjects. Each subject is followed by the names of speakers who have undertaken to help in the discussion:—

(*a*) Drawing Office Methods.	Mr. S. Camm, F.R.Ae.S. Mr. M. Langley, F.R.Ae.S.
(*b*) Application and Correlation of Wind Tunnel and Full-Scale Testing.	Mr. D. L. Ellis, A.F.R.Ae.S. Mr. R. H. Francis.
(*c*) Vibration Problems.	Dr. A. G. Pugsley, A.F.R.Ae.S. Dr. Ker Wilson.
(*d*) Tolerances, Limits and Inspection.	Mr. L. G. Fairhurst.
(*e*) Drag Reduction.	Mr. W. G. A. Perring, A.F.R.Ae.S. Mr. R. L. Lickley, A.F.R.Ae.S.

(*f*) Control Surface Design.	Mr. R. T. Youngman, F.R.Ae.S. Mr. H. B. Irving, F.R.Ae.S.
(*g*) The Future of Civil Aviation.	Dr. H. Roxbee Cox, F.R.Ae.S. Mr. W. L. Runciman.

The Council will appreciate suggestions for further subjects from members of the Society.

Society's Awards.

The Council invite entries from Students and Graduates for the following awards. Entries should be made by August 31st, 1941, at the latest.

Pilcher Memorial Prize.—This is awarded annually, at the discretion of the Council, for the best paper by a Student on heavier-than-air craft or any analogous subject.

Ushorne Prize.—This prize is awarded annually, at the discretion of the Council, for the best paper by a Student on some subject in connection with aero engines.

R. P. Alston Memorial Prize.—This prize is awarded annually to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control.

Journal Articles.

The Editor will be glad to consider any papers, particularly on the practical side of aviation, for publication in the Journal.

Amy Johnson Memorial Fund.

The Womens' Engineering Society is appealing for a fund to found a scholarship in aviation for women, in memory of Amy Johnson.

Amy Johnson, an Associate of the Royal Aeronautical Society, and a President of the Womens' Engineering Society, lost her life while acting as a ferry pilot in the Air Transport Auxiliary, on January 5th, 1941.

The Secretary has been appointed on the Appeal Committee for the fund. Many will have vivid memories of one of the most remarkable women pioneers, and it is in the hope that they—and others—will help to perpetuate the memory of this great pilot—that this appeal is made. Any sums, however small or big, will be welcome, and should be addressed to the Amy Johnson Memorial Fund, c/o Royal Aeronautical Society, 4, Hamilton Place, W.1.

Associate Fellowship Examination.

The following candidates were successful in the May Associate Fellowship Examinations:—

T. E. G. Bowden ...	Applied Mathematics. Aerodynamics. Design (Aircraft).
A. W. Brittain ...	Theory of Internal Combustion Engines. Aircraft Materials.
P. Farr	Applied Mathematics. Aerodynamics.
D. G. S. Grant ...	Pure Mathematics.
J. A. Hawes	Pure Mathematics. Strength of Aeronautical Materials and Structures. Design (Aircraft).
G. M. Magill	Theory of Machines.
R. B. Marsh	Design (Aero Engines).
J. K. Moakes	Aircraft Materials.

G. M. Parker	Applied Mathematics (First Place). Theory of Machines.
F. Pawling	Pure Mathematics. Theory of Machines (First Place). Design (Aircraft).
D. B. Pelly	Design (Aircraft).
Mrs. M. H. Polanyi ...	Pure Mathematics (First Place).
N. Purssell	Applied Mathematics. Strength of Aeronautical Materials and Structures. Design (Aircraft).
F. J. Samuely ...	Pure Mathematics. Theory of Internal Combustion Engines (First Place). Design (Aircraft).
F. Simpson	Aircraft Instruments (Theory and Design).
W. J. Strang ...	Design (Aircraft) (First Place). Aerodynamics (First Place). Strength of Aeronautical Materials and Structures (First Place).
H. D. Tabakman ...	Applied Mathematics.
D. B. Wallis	Design (Aero Engines).
D. H. Whaley ...	Theory of Machines.

The Baden-Powell Memorial Prize.

The Major Baden-Powell Memorial Prize has been awarded to Mr. W. J. Strang, who is considered by the Examiners to be the best Student in the May, 1941, Examinations.

Election of Members.

The following members were recently elected:—

Associate Fellows.—Hugh Graham Conway, William Henry Lindsey, Julius Ratzersdorfer, Charles Garrett Williams, Reginald Thomas Wood (from Associate).

Associates.—George Lewis Adamson, William Brittnel-Scott, Charles Frederick Hughesdon.

Graduates.—William Tait Dow (from Student), Alexander Walter Fielder, Frank Frodin (from Student), Bernard Ivo Goodwin.

Students.—Noel John Breslin, Michael Alec Garnett, George Thomas Hayes, Rodney Melling, Stanley Thomas Naismith, Samuel Whiteley.

Companions.—Miss Mary Berta de Bunsen, G. Temple.

Acknowledgments.

The Council acknowledge with deep appreciation a gift to the Society from the President, Mr. Griffith Brewer, of a stop-watch used by Wilbur Wright at Le Mans in 1908; and a letter dated September 26th, 1908, in Wilbur Wright's handwriting, to Mr. Brewer. Both these mementos of Wilbur Wright are of outstanding historical interest.

The Council have also to acknowledge the gift from Messrs. Rolls-Royce, Limited, of a painting by Ambrose McEvoy of Sir Arthur Whitten Brown, the navigator of the first aeroplane, the Vickers-Vimy, to cross the Atlantic. The pilot was the late Sir John Alcock, and the crossing was made from St. John's, Newfoundland, to Clifden (Co. Galway), on June 14-15th, 1919, in 16 hours 12 minutes. The painting, valued at £1,000, will be a reminder in the offices of the oldest aeronautical society, that the first non-stop, direct Atlantic crossing was made in a British machine by British personnel.

The Council have gratefully accepted the gift from Dr. F. J. Poynton, M.D., F.R.C.P., London, of a rare balloon table. The table has on its top a painting representing the first aerial voyage of Pilatre de Rozier and the Marquis d'Arlandes across Paris, on November 1st, 1783. The table was undoubtedly designed and constructed round about that period and will form one of the most interesting and valuable additions to the growing collection of historical relics of the early days of the conquest of the air now in possession of the Society.

The Council acknowledge with grateful thanks the gift of Journals from Mr. H. E. Wimperis, Fellow, and Sir Robert McClean, Fellow.

The Council also acknowledge the gift of £1 1s. for the purchase of a book for the Library from Mr. R. Perry, Associate. The Society has acquired with the donation a Programme of the International Exhibition of 1885 held at the Alexandra Palace where an Aeronautical Exhibition was held under the auspices of the Society.

Additions to the Library.

Pamphlet Literature in italics, with location reference following in brackets. Books marked * or ** are not available for loan.

B.a.21.—British Fighter Planes. By C. G. Grey. Faber and Faber. 1941. 5/-.

D.b.163.—*Ocean Air Transport.* (*29th Wilbur Wright Memorial Lecture.*) *By J. T. Trippe.* 1941. (PD.1-21.)

D.e.33.—*Military Aircraft Production: Present and Future of Commercial Aviation.* (*Press Release.*) *By Col. John H. Jouett. Aeronautical Chamber of Commerce of America.* 1941. (Y.6.b.24.)

E.b.85.—Practical Solution of Torsional Vibration Problems. (2nd Ed., Vol. 2.) By W. Ker Wilson. Chapman and Hall. 1941. 42/-.

I.a.19.—Elementary Mathematics for Wireless Operators. By W. E. Crook. Sir Isaac Pitman. 1941. 3/6.

J.b.13.—*India Meteorological Department. Scientific Notes, Vol. VIII, No. 89. Synoptic and Aerological Study of a Thunderstorm Day at Agra, Dec. 3, 1936. By S. Basu and Ram Sahay. Manager of Publications, Delhi.* 1940. 1/6.

L.k.39.—*Navy and Air Force Welfare. By Capt. R. W. Blacklock, R.N., and Group Captain F. C. Halahan. Royal Society of Arts.* (*Lecture delivered June 18th, 1941.*) (Y.12.b.20.)

Q.a.141.—*Loan Library Catalogue* (1938 *Supplement*). *Institution of Civil Engineers.* 1938. (PQ.1.a.8.)

Q.b.61.—Carnegie United Kingdom Trust: 27th Annual Report (1940). 1941.

Q.d.47.—*Eighth Report from the Select Committee on National Expenditure. House of Commons. H.M.S.O.*, 1940. 3*d*. (PQ.1.b.10.)

**R.b.215.—*Aeronautical Exhibition, under the Patronage of the Aeronautical Society of Great Britain, opening 1st June*, 1885. (*Prospectus drawn up by F. W. Brearey.*)

*RR.110.—Manuel de l'Aviateur-Constructeur. By M. Calderara and P. Banet-Rivet. Dunod and Pinat, Paris. 1910.

S.d.23.—Defeating the Bomber. By H. E. Wimperis. J. M. Dent and Sons. 1941. 1/-.

S.e.25, 26.—*The Battle of Britain. Ministry of Information.* 1941. 3*d*. (PS.3.a. 13 and 14.) Two copies.

J. Laurence Pritchard, *Secretary and Editor*

STRESS ANALYSIS OF AIRCRAFT FRAMEWORKS.

N. J. Hoff.*

Summary.

It is shown that the calculation of the critical loads of a plane framework is superfluous if the bending moments in the bars due to external moments and to lateral loads are determined by the Hardy Cross moment distribution method as extended by James. Convergence of this method is a proof of the stability of the framework. In Section 1 methods of determining stresses and critical loads in frameworks are discussed. Section 2 deals with the distortion patterns of beam columns on several supports below and above the critical loads. In Section 3 the method of proof of the convergence is outlined, and regular and particular cases are discussed with the aid of numerical examples. The final proof is given in Section 4.

1. Introduction.

In the last few years both theoretical and experimental research in aircraft structures have largely been devoted to the development of the monocoque type of design. However, the author believes that it is worth while spending some time on methods related to frameworks. The welded steel tube framework fuselage will probably always prove advantageous for small and cheap types unless built in very large numbers. Framework girders can be found even in monocoque aircraft. Also there may exist some further possibilities for the development of framework structures for aircraft; examples for such are the monospar and geodetic constructions. Moreover, the importance of the framework in other fields of engineering is obvious. In the following, therefore, a brief outline of the methods of stressing plane frameworks is given, and a new procedure of checking the instability devised. In order to fix ideas, a plane side panel of a framework fuselage will be considered though the conclusions also hold for a wider range of framework structures.

As is well known, the classical theory of frameworks assumes the bars to be connected by pin-joints. In addition, a refinement of this theory has been developed which considers the bending stresses, the so-called secondary stresses, caused by rigid connections at the joints. These secondary stresses will not be dealt with in the present paper, since they have but little effect upon the load carrying capacity of the framework, except perhaps in certain cases of fatigue failure. Of very great importance upon the strength of the structure are, however, the bending stresses caused by loads which are directly applied to the bars between the joints, contrary to the assumptions of the framework theory. Such loads always exist in actual aircraft (for instance, pilot's seat, bearings and attachments of control devices, and dashboard) and failure to calculate their influence has a very adverse effect upon the safety of the structure. Due to the rigid joints the influence of these loads extends over the entire framework. The fundamental concepts involved in their determination, as well as in that of the secondary stresses, were developed by Manderla in 1880. The calculations required are, however, too complex for routine work. Great importance,

* Polytechnic Institute of Brooklyn, Brooklyn, New York. The major part of the paper was written while the author was at Stanford University. For their criticism he is indebted to Professor S. Timoshenko, and to Professor A. S. Niles who brought the problem to his attention.

therefore, must be attributed to the moment distribution method published by Hardy Cross* in 1930 by which even the less theoretically minded can easily solve problems of bending of bars in frameworks. In 1935 in a thesis at Stanford University James (Ref. 6) showed that in aircraft frameworks the influence of the end loads in the bars upon the moment distribution is very important. This influence can be allowed for by a suitable choice of the constants of the Cross method, namely, the stiffness factor S and the carry-over factor C. In 1938 E. E. Lundquist and W. D. Kroll (Ref. 9) published tabulated values of these constants.

In addition to the calculation of stresses, as outlined above, it is necessary to ascertain that the compressive forces in the bars are below their critical values. Since Euler's solution of the problem of buckling in 1757 it has been known that the straight lined form of equilibrium of an originally straight bar becomes unstable at the critical value of the end load, and that bars subjected to loads near to or exceeding the critical values buckle and eventually collapse. The magnitude of the critical load is, however, greatly dependent upon end conditions, that is upon the amount of elastic restraint exerted by the joints at the ends of the bar. Hence, much unnecessary weight would be added to an aircraft panel by neglecting this restraining effect. On the other hand, the assumption of a constant end-fixity factor, as often done, is entirely unwarranted, since the restraint depends upon the sizes and loads of all bars of the framework and its actual value can be entirely different even for the same bar under different conditions of loading. Hence, a more detailed treatment of the problem is necessary.

Such a detailed treatment has been possible since 1923 when von Mises (Ref. 10) developed the general theory of instability of systems of bars. By his procedure the buckling load of the framework as a whole can be calculated. Unfortunately, the computations are too involved for routine work. Intermediate to the consideration of the entire framework as a unit and to assuming each bar as independent by inserting imaginary pins at all joints, is the concept of sub-dividing the framework into groups of bars. According to this procedure each heavily loaded compression member builds a group with some tension members and lightly loaded compression members attached to its ends. Members of the same group are assumed to be rigidly connected whereas between the different groups pins are inserted. Methods based upon this idea have been suggested by Teichmann, Borkmann, Osgood, Prager, and in an earlier issue of this Journal by the present author (Refs. 18, 1, 13, 16, 3). The common features of these methods are that they underestimate the load carrying capacity of the structure, but even so their conscientious use is rather laborious since the best choice of sub-dividing the framework into groups is different for every loading condition.

In all these calculations it should be borne in mind that the critical stresses in a given system of bars correspond to certain characteristic values of the loads and have nothing whatsoever in common with the ultimate stresses of strength of the material. As a matter of fact, it often happens that the results of calculations show combined direct and bending stresses well below the allowable limits in frameworks subjected to loads higher than the critical. On the other hand, the bending moments and stresses in bars subjected to the critical, or nearly critical values of the end loads are always found to be very high. This behaviour was first noticed by aeronautical engineers during the first World War when calculating the strength of braced biplanes. Their experience proved that it is necessary to check separately the stresses against the allowable values and the magnitudes of the loads against their critical values. This consideration together with the above-mentioned sub-division of the framework into groups

* The reader is assumed to be conversant with the Hardy Cross method. The concise original paper (Ref. 2) is explained in more detail in a paper by H A. Williams (Ref. 21) and in Niles and Newell's textbook (Ref. 11).

of bars enters into Lundquist's method of determining critical loads (Ref. 8). The criterion of instability is thereby obtained by the use of the Cross method.

In the present paper a simpler procedure for analysing frameworks is suggested which is based on certain convergence criteria of the Hardy Cross method to be proved in subsequent sections of this paper. According to this procedure the end loads and the stiffness and carry-over factors are first determined for every bar. Then for stability two inequalities must hold, the first of which is

$$L/j < 2\pi \text{ for every bar in compression.} \quad . \quad . \quad . \quad (1)$$

In this equation j is defined as

$$j^2 = EI/P \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and L is the length of the bar, E Young's modulus, I the moment of inertia, and P the compressive end load in the bar. Therefore, the relation of the symbols here used to those in Pippard and Pritchard's textbook is (Ref. 15)

$$2\alpha = L/j \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

In Timoshenko's " Theory of Elastic Stability " (Ref. 20)

$$2u = L/j \quad . \quad . \quad . \quad . \quad . \quad . \quad (3a)$$

Since $L/j < 2\pi$ corresponds to the buckling load for perfect rigidity of the fixation of both ends of the bar against rotation, obviously it represents an upper limit for the buckling load which cannot be reached by any elastic end fixity actually present in frameworks. The second inequality is

$$\Sigma S < 0 \text{ for every joint,} \quad . \quad . \quad . \quad . \quad (4)$$

where S is the stiffness factor of the Cross method defined as the (bending) end moment required at one end of the bar (support 1 in Fig. 1) to cause unit rotation of this end while the other end, the so-called far end of the bar (support 2) is held rigidly fixed against rotation. The summation in Eq. (4) extends over all bars attached to the joint under consideration. Therefore, inequality 4 states that a positive moment is required at the joint under consideration in order to cause a positive rotation of the joint. This means that a rotation can only be obtained if work is done by the external moment. This is, however, the criterion of stability. Since the stiffness S is calculated upon the assumption of a rigid fixation of the far end of every bar, and the actual end fixity in frameworks is always less, Eq. (4) represents a minimum requirement of the stability of the framework.

If in a framework the necessary but not sufficient criteria of stability Eqs. (1) and (4) are fulfilled by every bar and by every joint respectively, the following Theorem 1 holds:—

" A necessary and sufficient criterion of the stability is the obtainment of a finite unique set of values for the end moments by a straightforward application of James's version of the Cross method."

The important consequence of this theorem is that it entirely dispenses with a separate check of the stability of a framework if the bending moments in the bars are calculated by the Cross method. Since the bending moments due to loads applied between joints must be determined anyway, and since the simplest method for obtaining them is the Cross method, the statement of the theorem results in a great simplification of the stressing of frameworks. Some explanatory remarks to the theorem may be of interest. A finite set of values means that the Cross method converges and that after a few cycles the moments to be balanced tend to decrease. Uniqueness of the solution means that the results must be independent of the order of balancing. In general this is the case, but the statement is of importance for some special cases explained in the examples. Furthermore, it is assumed that the method is used in a straightforward way, that is as suggested by Hardy Cross and usually done by civil engineers. The theorem does not hold if the procedure of Cross is only used to obtain closed general formulas as in the paper by Lundquist. Also, it is understood that the

stiffness S and the carry-over factor C must be calculated with due regard to the effects of the end loads in the bars, as suggested by James (Ref. 6) and tabulated by Lundquist and Kroll (Ref. 9).

Therefore, the suggestions of the present paper for a complete analysis of a framework can be summarised as follows. The end loads in the bars should be determined by any routine method, for instance by a reciprocal diagram. Then the values of the stiffness and carry-over factors can be calculated. These must satisfy the inequalities 1 and 4. The distribution of the bending moments in the bars due to external loads applied between the joints should be calculated by the Cross method. If this converges, that is, if the moments to be balanced tend to decrease after a few cycles, the framework is known to be in stable equilibrium. If the method diverges, that is the moments to be balanced tend to increase in subsequent cycles of the procedure and thus no definite moment distribution can be obtained, the framework is unstable. However, in very special cases convergence can exist though the equilibrium is not stable. Such cases can easily be detected by changing the order of the balancing. Thereby the method either becomes divergent, or if again a definite moment distribution is obtained, it is different from the one first arrived at. This behaviour is discussed in detail and explained with the aid of examples in Sections 3 and 4. The proof of Theorem 1 is the subject matter of the sections which follow.

2. The Distortion Pattern of Systems of Bars.

An actual framework under loading, as distinct from an ideal one, consists of a number of beam-columns, namely, of bars upon which end loads, end moments and eventually side loads are acting simultaneously. With a view to obtaining an insight into the different possible patterns of elastic distortions of a framework, some characteristics of beam-columns are discussed below. Following that a proof of Theorem 1 is given for the simplest type of a group of bars rigidly connected, namely, a continuous beam-column on several supports.

The notation and sign convention used in the present paper is shown in Fig. 1.

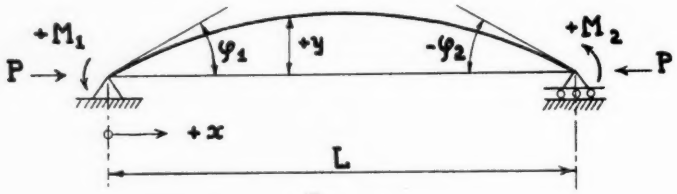

Fig. 1.

It follows from the differential equation of a beam-column as developed in standard textbooks on aeroplane structures* that the connection between end moments and end tangents can be expressed by the following equations:—

$$\left.\begin{aligned} M_1 &= \mu K\phi_1 + \mu' K\phi_2 \\ M_2 &= \mu' K\phi_1 + \mu K\phi_2, \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where

$$K = EI/L \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and the coefficient μ and μ' are

$$\left.\begin{aligned} \mu &= \left(\frac{L}{j}\right)\frac{(L/j)\cos(L/j) - \sin(L/j)}{(L/j)\sin(L/j) + 2\cos(L/j) - 2} \\ \mu' &= \left(\frac{L}{j}\right)\frac{\sin(L/j) - (L/j)}{(L/j)\sin(L/j) + 2\cos(L/j) - 2} \end{aligned}\right\} \quad . \quad . \quad . \quad (7)$$

* E.g., Chapter VII of Ref. 15, Chapter XIV of Ref. 11; see also Chapter I of Ref. 20.

The functions μ and μ' can be expressed in the following way by the Berry functions which appear in Pippard and Pritchard's textbook (Ref. 14):—

$$\mu=\frac{12\,\Phi(\alpha)}{4\,\Phi^2(\alpha)-f^2(\alpha)} \qquad \mu'=\frac{4\,\Phi^2(\alpha)-f^2(\alpha)}{6\,f(\alpha)} \quad . \quad . \quad (8)$$

The formulas given in Timoshenko's " Theory of Elastic Stability " (Ref. 20) can be obtained from Eqs. (8) by the substitutions:—

$$f(\alpha)=\Phi(u) \text{ and } \Phi(\alpha)=\Psi(u) \quad . \quad . \quad . \quad . \quad (9)$$

Eqs. (8) can also be used to obtain the connection between μ and μ' and the functions α and β in Niles and Newell's textbook (Ref. 11) if the following substitutions are made:—

$$f(\alpha)=\alpha \text{ and } \Phi(\alpha)=\beta \quad . \quad . \quad . \quad . \quad (10)$$

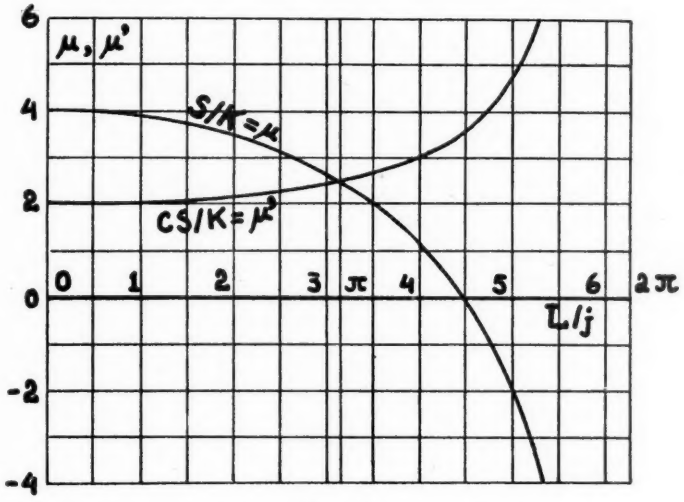

FIG. 2.

A graphic plot of the coefficient μ and μ' against $L/j=2\alpha$ is given in Fig. 2. It is worth while noting that it follows from Eqs. 5 and from the definition of the coefficients of the Hardy Cross method that

$$\mu=S/K \text{ and } \mu'=CS/K \quad . \quad . \quad . \quad . \quad (11)$$

Of the symbols in Eqs. (11) the stiffness S was defined in Section 1 in conjunction with Eq. (4). The carry-over factor C can be defined by stating that CS is the moment required at the far end of the beam (support 2) for keeping its slope unchanged at the far end support while a moment S is applied at the near end (support 1).

If on the beam of Fig. 1 the left end moment M_1 alone is acting ($M_2=0$), the end slopes can be expressed by the Berry functions* as follows:—

$$\phi_1=M_1\Phi(\alpha)/3\,K \text{ and } \phi_2=-M_1 f(\alpha)/6\,K \quad . \quad . \quad . \quad (12)$$

With the aid of the tabulated values of the Berry functions it is easily seen that for small loads ϕ_1 is positive and ϕ_2 negative, according to the present sign convention. Increasing the end loads, that is increasing (L/j) causes the magnitude of both end slopes to increase and for $(L/j)=\pi$ to become infinite. This means that the beam-column becomes unstable at the so-called first critical

* See p. 349 of Ref. 15. For values $2\alpha>\pi$ p. 499 of Ref. 20 or p. 72, Vol. 2 of Ref. 11 should be consulted.

value of the end load $P=\pi^2EI/L$. Since, however, with a further increase of the end load the slopes again become finite it is worth while investigating how such equilibrium conditions are possible.

The three sketches of Fig. 3 show the deflected shape drawn to the same scale of a beam-column under the same constant external moment M_1 for three different values of the end load P characterised by three different values of (L/j).

For $0 < L/j < \pi$, $\Phi(\alpha) > 0$ and $f(\alpha) > 0$.

The left end of the beam-column rotates in the direction of M_1, the right end in the opposite direction. This equilibrium is stable; if the deflection of the bar is increased or decreased by applying a small transverse force at midspan, the bar will return to its original deflected shape after the disturbing force is removed.

For $\pi < L/j < 4.49$, $\Phi(\alpha) < 0$ and $f(\alpha) < 0$.

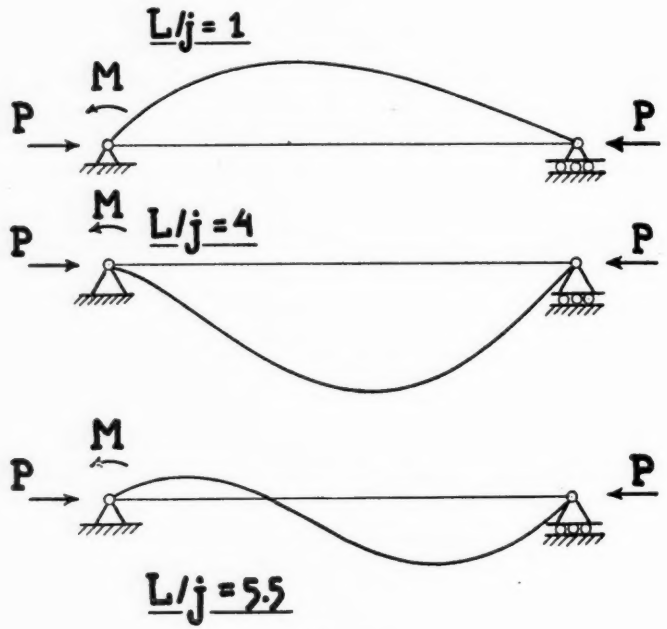

FIG. 3.

The left end rotates against M_1, the right end in the direction of M_1. This equilibrium is unstable. Any deviation from the distortion pattern of equilibrium shown in the figure, provoked by a disturbing force, results in ever increasing further deviations and ultimately in failure, even if the disturbing force is removed after a short duration of action. On the other hand, stable equilibrium of the same deflection pattern is well possible if M_1 is an elastic restraining moment rather than a constant external moment, and the deflections are caused by some initial curvature of the bar or by an eccentricity of the axial loads.

For $4.49 < L/j < 2\pi$, $\Phi(\alpha) > 0$ and $f(\alpha) < 0$.

Both ends rotate in the direction of M_1. This equilibrium is again unstable and every disturbance of the deflection precipitates increasing deviations from the state of equilibrium. In this case, however, the assumption of an elastic restraint against rotation at the left support, instead of an external moment,

would not have the required stabilising effect as in the previous case, since obviously not even rigid encastrement would suffice, for the reason that the end load is higher than the critical load for one pinned and one rigidly encastred end.

Values of (L/j) greater than 2π need not be considered since with such high axial forces the beam-column cannot be stabilised by any amount of restraining end moments. Such bars, therefore, must not be allowed in actual frameworks.

The foregoing example shows that the equations of equilibrium of beams under combined bending and end load can be satisfied even if the axial loads are higher than their critical values. Practical experience shows, however, that in actual structures unstable equilibrium cannot be maintained. The upper limit of the load-carrying capacity of a system of bars is determined, therefore, either by the maximum allowable stresses due to simultaneous bending and axial load, or by the critical loads, whichever value is first reached. In the case of a single bar with known end conditions the determination of the critical load is always an easy matter. This is, however, not so with systems of bars and the necessity of calculating the critical loads imposes a heavy burden upon the stress analyst. The elimination of this requirement is considered as the achievement of the present paper.

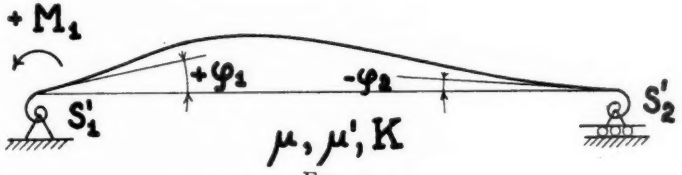

FIG. 4.

Somewhat more involved than the beam-column on simple supports is the continuous beam-column on several supports. Fig. 4 represents such a structure in a manner convenient for analysis. Only one span of the continuous beam is directly shown and the remainder are replaced by two coiled springs at the supports. The spring is chosen so that under a given moment M it rotates through an angle equal to the change of slope of the cut-off portion it replaces. Consequently the stiffness S'_1 is the moment which when applied at support 1 would cause a unit rotation of the end tangent of the cut-off portion of the continuous beam-column at support 1. In order to include in the discussion cases when the cut-off portions of the continuous beam-column are by themselves beyond the stability limit, S'_1 and S'_2 are allowed to have any positive or negative values.* Moments acting on the beam in counter-clockwise direction and counter-clockwise rotations are considered positive.

With the aid of Eqs. (5) the condition of the equilibrium of moments at the supports can be written

$$\left.\begin{aligned} \phi_1(\mu K + S'_1) + \phi_2 \mu' K &= M_1 \\ \phi_1 \mu' K + \phi_2(\mu K + S'_2) &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (13)$$

The slopes at the supports are, therefore, given by

$$\left.\begin{aligned} \phi_1 &= \frac{(\mu K + S'_2)}{(\mu K + S'_1)(\mu K + S'_2) - (\mu' K)^2} M_1 \\ \phi_2 &= \frac{-\mu' K}{(\mu K + S'_1)(\mu K + S'_2) - (\mu' K)^2} M_1 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (14)$$

* This system cannot stand for a general truss since in such the elastic systems represented by the springs are interdependent. To make it represent the general case two different carry-over factors are needed allowing for the effect of spring 1 on spring 2 and vice versa. These factors can have any positive or negative values.

In the case of a continuous beam-column on several supports to which an external moment M_1 is applied but upon which no axial forces are acting evidently all symbols in Eqs. (14) are positive. Also, from Fig. 2 for the no end load condition $\mu=4$ and $\mu'=2$. Consequently the denominator is positive and the deflection pattern corresponds to that of Fig. 3*a*. Then the axial loads are assumed to be increased with the effect that μ decreases and μ' increases according to Fig. 2, and S'_1 and S'_2 may increase or decrease. The system becomes unstable when the denominator vanishes, and it is clear from Eq. (14) that such will be the case before either one of the expressions $(\mu K+S'_1)$ and $(\mu K+S'_2)$ will change sign. Since, however, μ' is always positive in the entire range of interest of the present investigation, namely, for $0<(L/j)<2\pi$ in compression and for any value of (L/j) in tension, the following important result can be stated: Under a positive moment M_1 at support 1 the slope of the continuous beam-column is positive at support 1 and negative at support 2, if the structure is in stable equilibrium.

It is of importance to show that the converse also holds true. Indeed, the conditions for $\phi_1>0$ and $\phi_2<0$ in the range $0<(L/j)<2\pi$ where μ' is positive, can be stated as

$$\left.\begin{aligned}&(\mu K+S'_1)>0,\ (\mu K+S'_2)>0,\\ &\text{and } (\mu K+S'_1)(\mu K+S'_2)-(\mu' K)^2>0,\end{aligned}\right\} \quad . \quad . \quad . \quad (15)$$

which inequalities are satisfied only below the first critical condition, q.e.d.

The conditions in the adjacent span of the continuous beam-column on several supports can be investigated by considering the moment acting at support 2 from the first span upon the second span as the external moment of the second span. This moment is the reaction of the end moment acting at support 2 upon the first span and will be denoted M_2:—

$$M_2=-\phi_1\mu' K-\phi_2\mu K=\frac{-\mu' K M_1}{(\mu K+S'_1)(\mu K+S'_2)-(\mu' K)^2}S'_2 \quad . \quad (16)$$

Eq. (16) shows that in case the entire structure is stable the moment acting upon the second span at support 2 has a sign opposite to M_1, if the portion of the structure to the right of the second support is by itself stable, and its sign is equal to that of M_1, if this portion is by itself unstable.

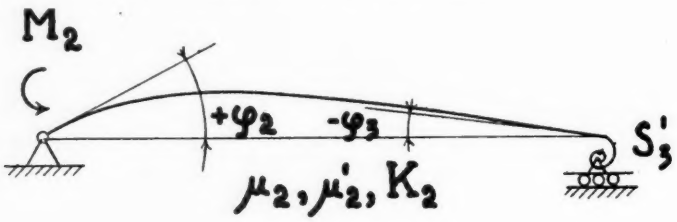

FIG. 5.

The second span shown in Fig. 5 differs from the first span inasmuch as the effect of the portion of the continuous beam-column to the left of support 2 is represented by the moment M_2 and, therefore, in Fig. 5 no coiled spring is needed at support 2. Consequently the slopes at the support can be written in analogy to Eqs. (14) as

$$\left.\begin{aligned}\phi_2&=\frac{(\mu_2 K_2+S'_3)}{\mu_2 K_2(\mu_2 K_2+S'_3)-(\mu'_2 K_2)^2}M_2\\ \phi_3&=\frac{-\mu'_2 K_2}{\mu_2 K_2(\mu_2 K_2+S'_3)-(\mu'_2 K_2)^2}M_2\end{aligned}\right\} \quad . \quad . \quad . \quad (17)$$

For stability

$$(\mu_2 K_2+S'_3)>0, \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which states that for stability the stiffness of the beam-column at the third joint must be found positive if calculated by assuming the structure to the right of support 3 as it is actually, and the left end of the second span as rigidly encastred at support 2. This is, of course, a necessary but not sufficient criterion of stability. Since further μ'_2 is always positive in the range investigated, the signs of the slope at the two supports must always be opposite as long as the entire structure is stable. As a conclusion it may now be stated as Theorem 2:—

"In the case of stable equilibrium the distorted shape of a continuous beam-column on several supports, with a single external moment acting at one of the supports, is such that the slopes at adjacent supports are of opposite sign, and the sign of the external moment and that of the slope at the support of application are equal. Conversely, if the deflection pattern is found to be as above stated, the structure is known to be in stable equilibrium."

Prerequisite to the validity of this theorem is the fulfilment of the inequality $(L/j) < 2\pi$ in every bar in compression.

Concluding this section it will be shown that if the end moments of the bars are determined by a straightforward application of the Hardy Cross method, it is not possible to obtain a set of finite end moments which does not correspond to the stable deflection pattern.

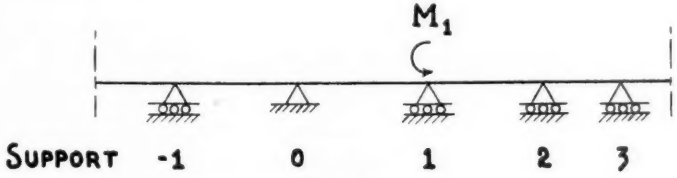

FIG. 6.

For this investigation an actual continuous beam-column on many supports (Fig. 6) and not the representative structure of Fig. 4 will be considered. Calculations will be restricted to cases in which $(L/j) < 2\pi$ for every member, $(L/j) < 4.49$ for members with one end pinned, and the sum of the stiffnesses ΣS is positive for every joint. In case these conditions are not satisfied obviously the beam-column is unstable and need not be investigated further.

First the external moment M acting at the first support will be distributed between the beams on either side of the first support. Then a carry-over moment $MC_1S_1/(S_0+S_1)$ must be applied at the second support. This will be balanced and the balancing moment, which is negative, distributed. The moment distributed to the first span causes a carry-back moment at the first support of a magnitude

$$-MC_1^2S_1^2/(S_0+S_1)(S_1+S_2).$$

By the requirements stated the sums in the denominator are positive, and so the carry-back moment must be negative. The new balancing moment to be distributed at the first support is, therefore, again positive. In the same way it can easily be shown that the moment carried back from the third support to the second support is positive and that after balancing this moment at the second support the corresponding carry-back moment at the first support will again be found negative. Therefore, all carry-over and/or carry-back moments are of the same sign at the same support and of opposite sign at consecutive supports. Since at each support the balancing moments divided by ΣS give the angle of rotation of the beam-column, the Hardy Cross method can only give a distorted shape in which the rotation at the first support is in the direction of the external moment and rotations at consecutive supports are of opposite sign. When the rotations are finite this shape corresponds to the stable equilibrium pattern discussed before. Therefore, by applying a finite number of steps of the Cross

method it is not possible to obtain any distortion pattern corresponding to unstable equilibrium.

Consequently, it can be stated that if the equilibrium of a continuous beam-column on several supports with a single external moment at one of the supports is unstable, a straightforward application of the Hardy Cross method of moment distribution cannot yield a finite set of end moments, that is the method is divergent. Hence, convergence of the moment distribution procedure is a proof of stability.

Extension of this statement to cases when several external moments are acting would involve the addition of divergent series. The great difficulties of a proof of the converse of the above statement, namely, of the convergence of the procedure in the stable case, may best be appreciated from a study of Oldenburger's paper (Ref. 12). In the case of a framework there is so much greater variety of possible distortion patterns and orders of balancing that the problem becomes very involved. For a single external moment and a predetermined definite order of the procedure the connection between stability and convergence was established by Lundquist (Ref. 8). A direct proof of Theorem 1, however, seems to present extreme difficulties and the problem, therefore, is attacked in the following sections by means of strain energy methods.

3. Systems with Two Degrees of Freedom.

In the present section Theorem 1 will be proved for systems of two degrees of freedom and the results discussed with the aid of numerical examples. The proof will be established by means of strain energy methods* and, therefore, the first step to be undertaken is to calculate the strain energy stored in the distorted structure. Since it is assumed that during the whole procedure of moment distribution the axial forces in the bars do not change, that part of the strain energy can be disregarded which is due to the work done by the axial forces during the displacements. A proof of this statement may be found under Section 4. Therefore, the strain energy U stored in a beam-column on two simple supports is equal to the work done by the end moments during displacements, that is

$$U = (1/2)\,(M_1\phi_1 + M_2\phi_2) \quad . \quad . \quad . \quad . \quad (19)$$

With the aid of Eqs. (5) this can be written:—

$$\left.\begin{aligned} U &= (1/2)\,\mu K\,(\phi_1^2 + \phi_2^2) + \mu' K\phi_1\phi_2 \\ &= (1/2)\,S\,(\phi_1^2 + \phi_2^2) + CS\phi_1\phi_2 \end{aligned}\right\} \quad . \quad . \quad . \quad (20)$$

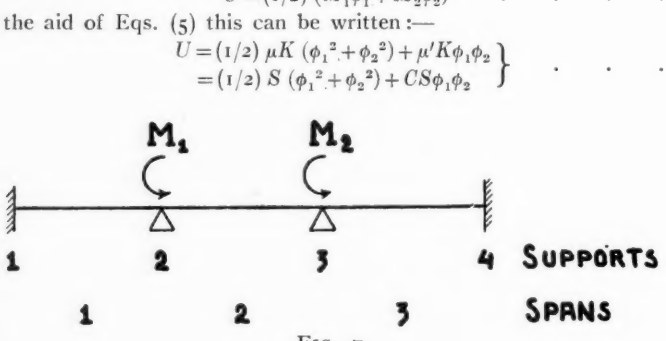

Fig. 7.

Fig. 7 represents the system to be discussed in the following deductions. It is a continuous beam-column on four supports, the first and last of which are rigidly encastred. From the present viewpoint this beam-column has two degrees of freedom, since its distorted shape can be fully characterised by two parameters, namely, by the rotations ϕ_2 and ϕ_3 at the two intermediate supports, provided the

* Detailed treatments of strain energy methods and of the principle of virtual displacements may be found in Refs. 14, 17 and 19.

axial loads in the bars are known. For given rotations ϕ_2 and ϕ_3 the strain energy in the structure is

$$U = (1/2)\,\phi_2^2\,(S_1 + S_2) + (1/2)\,\phi_3^2\,(S_2 + S_3) + \phi_2\phi_3 C_2 S_2 \quad . \quad (21)$$

since ϕ_1 and ϕ_4 are always equal to zero. If in a horizontal plane two perpendicular axes are taken to represent ϕ_2 and ϕ_3, and the vertical axis through the same origin to represent U, the strain energy will be represented by a second order surface in space. According to the value of the discriminant of the second order expression Eq. (21), called a quadratic form, it will be either a paraboloid, a hyperboloid with one sheet, or in the intermediate limiting case a cylinder. As readily seen, the surface contains the origin and has there a horizontal tangent plane.

This surface can easily be transformed into a surface representing the total potential energy of the system. The total potential energy can be defined as the strain energy less the potential of the external forces acting upon the system. In the present case this latter is simply

$$V = M_2\phi_2 + M_3\phi_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

Therefore, the total potential energy surface $(U - V)$ can be obtained from the strain energy surface by a linear transformation, that is by shifting and tilting. Thereby the origin remains on the surface, since no absolute terms are added, but the horizontal tangent plane of the surface does not pass through the origin any more.

This surface is closely connected to the stability of the system since it follows from the principle of virtual displacements* that the continuous beam-column is in equilibrium at such values of the rotations ϕ_2 and ϕ_3 for which the total potential energy has a stationary value, that is the surface has a horizontal tangent plane. Moreover, the equilibrium is stable if the stationary value is a minimum, and unstable if it corresponds to a saddle point as in the case of the hyperboloid. It cannot be a maximum as long as inequality 4 is fulfilled. The limiting case between stability and instability corresponds to the critical loads.

These results indicate that the stability of the continuous beam-column is fully characterised by the shape of the total potential energy surface. Moreover, the stability is independent of the moments applied at the joints, and, therefore, of the transverse loads also, since the curvature of the surface is not changed by the addition of the linear terms of the potential of the external moments. It depends only on the end loads in the bars which determine the value of the factors S and C. Now the proof of Theorem 1 is readily obtained with the aid of Theorem 3:—

"In each cycle of steps of the Hardy Cross method (balancing, distributing, carry-over) the total potential energy of the system decreases and attains its minimum value compatible with the fixed angles of rotations of all joints except the one which is being balanced."

This theorem can be proved by applying the principle of virtual displacements to a partial system consisting of the joint to be balanced and of all bars attached to it, the far ends of which are considered to be rigidly fixed. Such a partial system is always stable in the cases here considered, since Eq. (4) is the condition of stability for a partial system as explained. Therefore, the angle ϕ reached in each cycle of the moment distribution procedure corresponds to stable equilibrium, after in the course of a cycle a joint has been released and allowed to rotate, and thus in the partial system equilibrium of moments has been established.† By the principle of virtual displacements, however, stable equilibrium is characterised by a minimum of the total potential energy.

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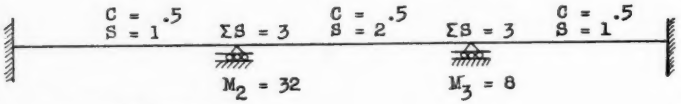
* See footnote 5.

† A formal proof that the Cross procedure conforms with the equations of moment equilibrium was given by the author in Ref. 5.

EXAMPLE I

STABLE EQUILIBRIUM



Support 2 balanced first:

5.33	10.66	21.33	10.66		
		-.885	-1.77	-.89	-.445
.147	.295	.590	.295		
		-.098	-.197	-.098	-.049
.016	.032	.066	.033		
			-.022	-.011	-.006
5.493	10.987	21.003	8.999	-.999	-.500

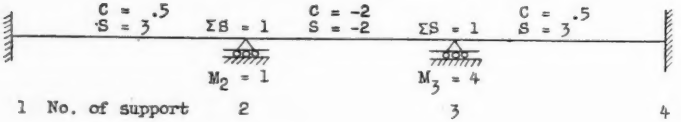
Support 3 balanced first:

		2.66	5.33	2.66	1.33
4.88	9.77	19.56	9.77		
		-3.26	-6.51	-3.26	-1.63
.55	1.09	2.17	1.09		
		-.363	-.727	-.36	-.18
.06	.12	.242	.121		
		-.040	-.080	-.04	-.02
	.01	.026			
	10.99	20.995	8.994	-1.00	-.50

FIG. 8.

EXAMPLE II

UNSTABLE EQUILIBRIUM



Support 2 balanced first:

	$M_2 = 1$		$M_3 = 4$		
1.5	3	-2	4	0	0

Support 3 balanced first:

	$M_2 = 1$		$M_3 = 4$		
		16	-8	12	6
-22.5	-45	30	-60		
		240	-120	180	90
-360	-720	480	-960		
⋮	⋮	⋮	⋮		⋮

FIG. 9.

The importance of Theorem 3 is that it gives a rule as to how to proceed on the total potential energy surface in each step of the balancing procedure. The starting point is, of course, always the origin since at the start the beam-column has a non-distorted shape. When balancing the second support of Fig. 7, the total potential energy changes along the line ϕ_3=const. The deepest point on this line corresponding to the minimum value of $(U-V)$ for ϕ_3=const. is reached after the cycle has been completed. In the next step ϕ_2 is held fixed and ϕ_3 varied along a line ϕ_2=const., and so on. In this way the equilibrium position can be approximated to any desired degree by a sufficient number of steps, in case the total potential energy surface is a paraboloid. If, however, it is hyperboloid or a cylinder, the steps lead toward negative infinity. This is the proof of Theorem 1.

For a better understanding of the results reached, and for an illustration of the "particular cases," three numerical examples have been worked out in detail and presented in Figs. 8 to 13.* The first three of these figures represent the continuous beam-column on four supports with the values of the stiffnesses and of the carry-over factors noted, and show the routine procedure of moment distribution. The last three of the figures represent the corresponding total potential energy surfaces by contour lines as used in topographic maps. The digit on the contour lines indicates the value of the total potential energy. The equation of the surface is given in the lower left corner of the figure and the path followed in consecutive steps of the balancing procedure is marked by heavy full or dotted lines.

EXAMPLE III

NEUTRAL EQUILIBRIUM

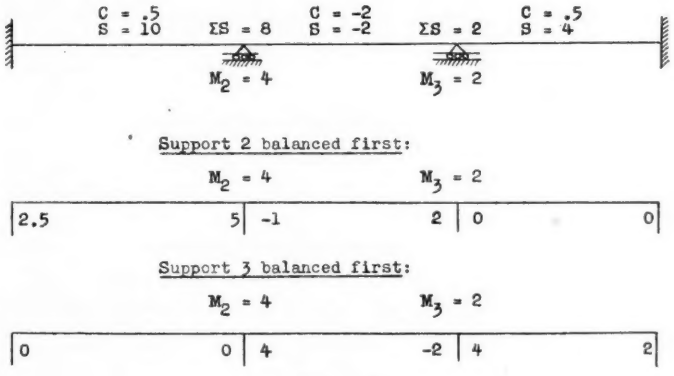


FIG. 10.

The first example, Figs. 8 and 11, represents the case of stable equilibrium. Starting from the origin, $\phi_2=\phi_3=0$, the deepest point on the paraboloid is approached in two different ways depending upon whether support 2 or 3 is balanced first. In each cycle of the procedure the deepest point of the surface is reached on a straight line (of the horizontal projection) running north or east respectively.

The second example, Figs. 9 and 12, corresponds to instability. If support 3 is balanced first the unbalanced moments increase in consecutive steps. The

* These figures were shown by the author at the 2nd Annual Summer Meeting of the Institute of the Aeronautical Sciences in June, 1940, at Pasadena, but have not appeared as yet in print. (Ref. 4.)

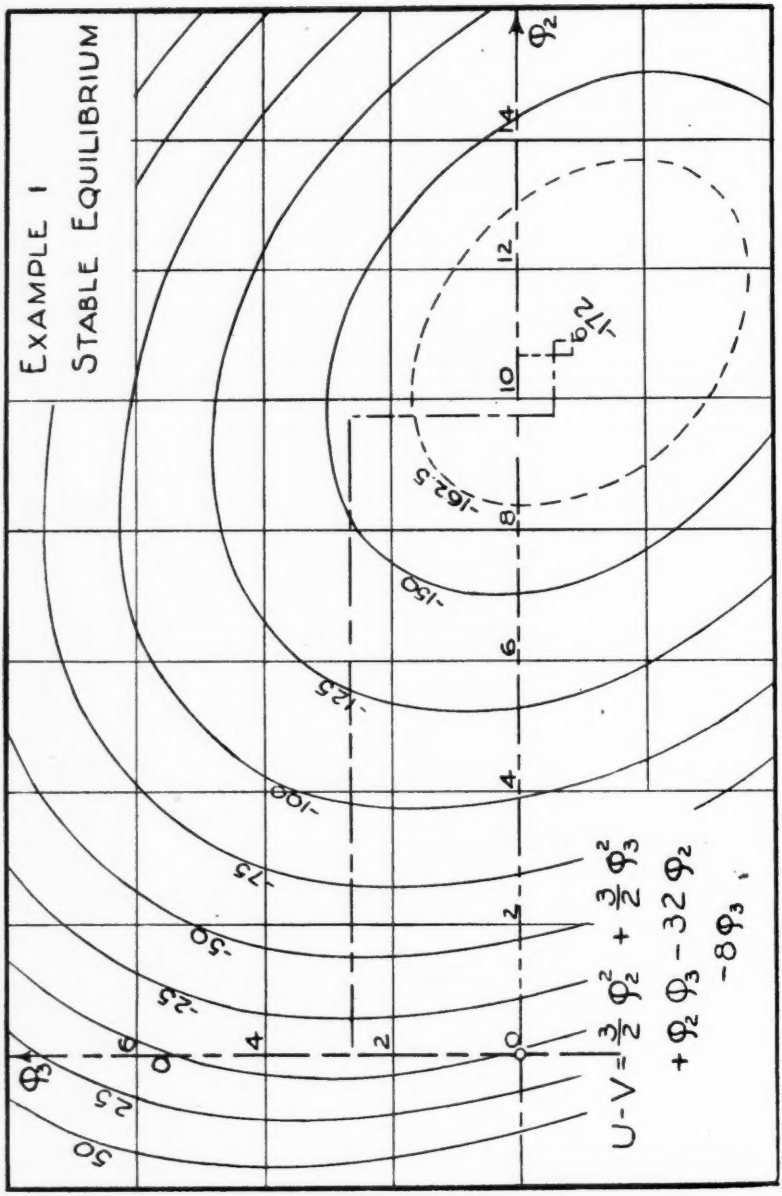

EXAMPLE 1
STABLE EQUILIBRIUM
Φ_3
Φ_2
$U-V=\frac{3}{2}\Phi_2^2+\frac{3}{2}\Phi_3^2$
$+\Phi_2\Phi_3-32\Phi_2$
$-8\Phi_3$
-162.5
-150
-125
-100
-75
-50
-25
-12.5
2
4
6
8
10
12
14

FIG. 11.

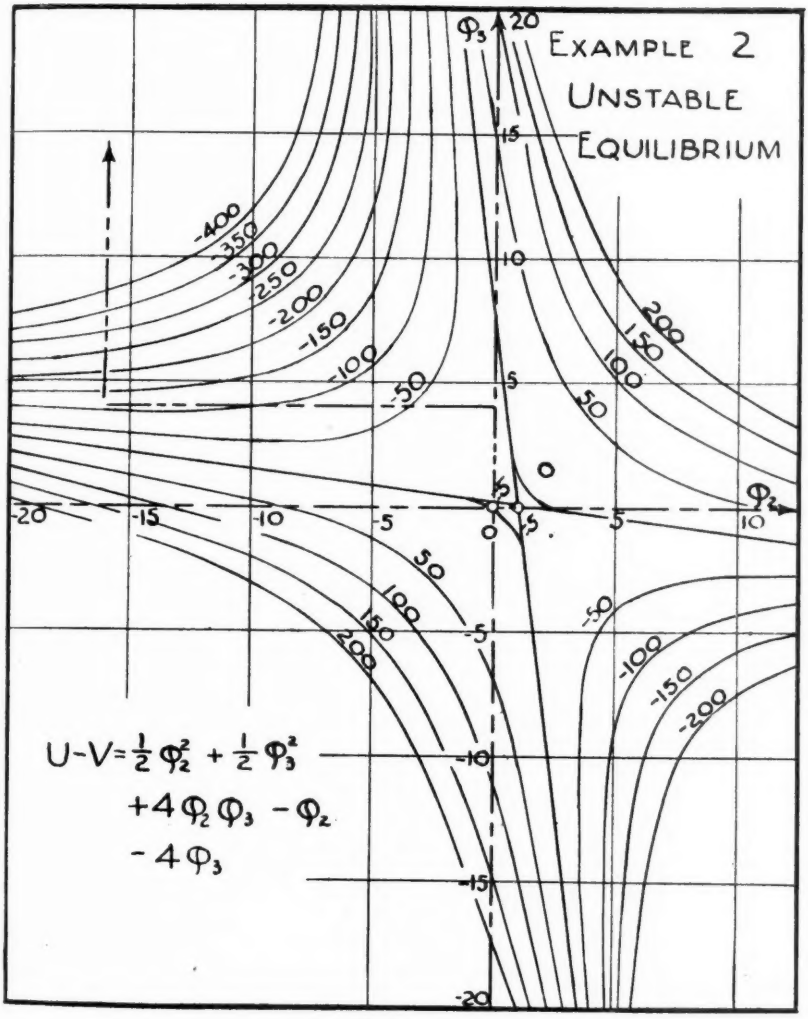

EXAMPLE 2
UNSTABLE
EQUILIBRIUM
Φ_3
Φ_2
20
15
10
5
0
-5
-10
-15
-20
-400
-350
-300
-250
-200
-150
-100
-50
50
100
150
200
$U-V=\frac{1}{2}\Phi_2^2+\frac{1}{2}\Phi_3^2$
$+4\Phi_2\Phi_3-\Phi_2$
$-4\Phi_3$

FIG. 12.

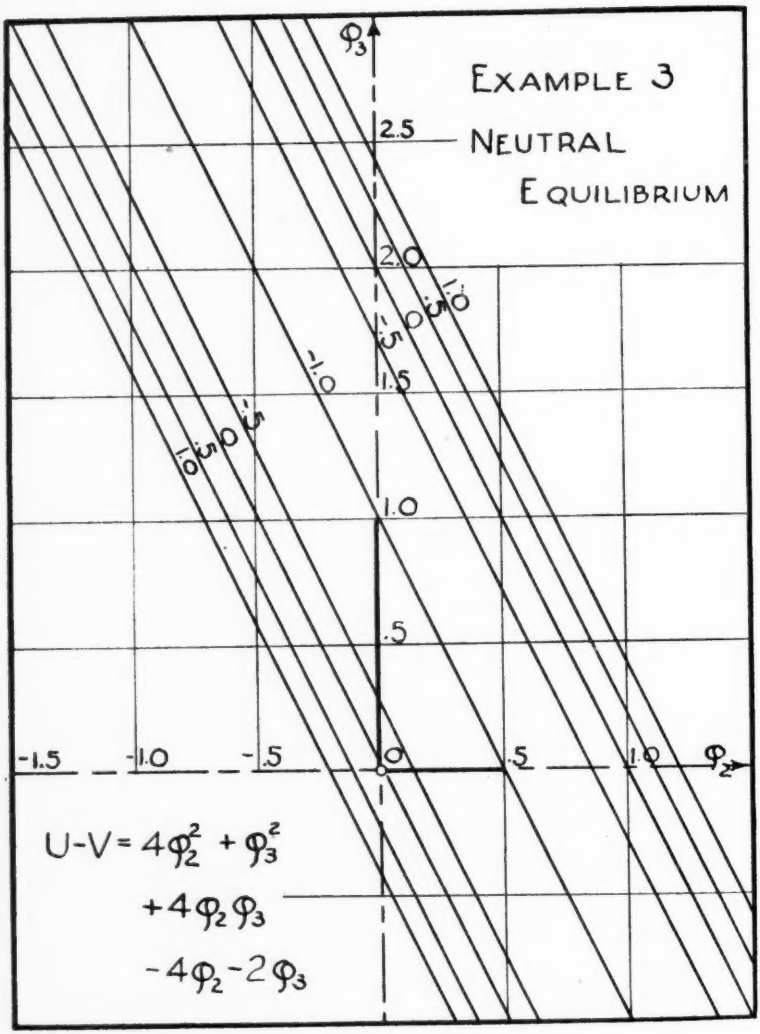
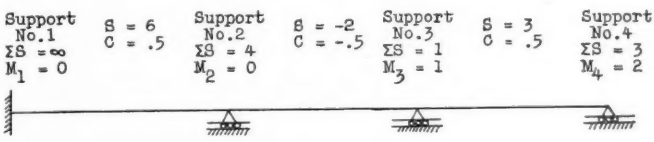

EXAMPLE 3
NEUTRAL
EQUILIBRIUM
φ_3
2.5
2.0
1.5
1.0
.5
-1.5
-1.0
-.5
0
.5
1.0
φ_2
$U-V = 4\varphi_2^2 + \varphi_3^2$
$+4\varphi_2\varphi_3$
$-4\varphi_2 - 2\varphi_3$

FIG. 13.

path on the hyperboloid leads into the north-western chasm and toward negative infinity. In such a way equilibrium, corresponding to the saddle point at $\phi_2 = -1$, $\phi_3 = 0$, can never be reached. This is the rule in the case of instability, but an exception is possible if the saddle point is on one of the co-ordinate axes. By a proper choice of the constants S and C and of the moments M_2 and M_3 such a particular case was purposely obtained for the second example. Then by balancing support 2 first, the saddle point corresponding to unstable equilibrium can be reached in a single step. Hence, the moment distribution procedure converges although the structure is unstable.

EXAMPLE IV

NEUTRAL EQUILIBRIUM



Order of balancing: supports 4, 3.

	$M_2 = 0$		$M_3 = 1$		$M_4 = 2$
	0	0	0	1	2
				1	2

Order of balancing: supports 3,2,4.

	$M_2 = 0$		$M_3 = 1$		$M_4 = 2$
		1	-2	3	1.5
-.75	-1.5	.5	- .25	.25	.5
-.75	-1.5	1.5	-2.25	3.25	2.0

Order of balancing: supports 3,4,3,2,4.

	$M_2 = 0$		$M_3 = 1$		$M_4 = 2$
		1	-2	3	1.5
				.25	.5
		-.25	.50	-.75	-.37
-.56	-1.12	.37	-.18	.18	.37
-.56	-1.12	1.12	-1.68	2.68	2.0

FIG. 14.

Example 3, Figs. 10 and 13, represents the limiting or critical case. The surface is a cylinder, in the general case inclined. Then equilibrium is altogether impossible. In the particular case of the third example the constants S and C and the applied moments have been so chosen that the cylinder is horizontal. Therefore, a stationary value of the total potential energy exists all along a straight line corresponding to neutral equilibrium which can be reached at either one of the two intersection points of the line with the co-ordinate axes. Therefore, here again the Cross procedure converges although no stable equilibrium is possible. However, such particular cases can easily be detected by carrying out the moment distribution procedure in two different ways. Then in the " unstable " case the alternate procedure is divergent, while in the " critical " case equilibrium is reached with two entirely different moment distributions.

This last phenomenon is further illustrated by example 4. This is shown in Fig. 14 which represents a system with three degrees of freedom. Here

equilibrium can be obtained with three entirely different moment distributions. Of course, a contour line map of the total potential energy surface could not have been drawn for this case.

It may be mentioned that the theoretically constructed particular cases of examples 2, 3, and 4 have been shown here only for the purpose of a thorough understanding of the principles involved but never, to the knowledge of the author, have they been observed in practical calculations.

4. Plane Frameworks.

When the principle of virtual displacements is used to investigate the stability of frameworks, the total potential energy of the system, that is the strain energy stored in the bars less the potential of the external loads, has to be expressed in terms of suitably chosen parameters representing distortions. For the present purposes it is convenient to take for parameters the extensions of the bars due to direct stress alone, and the rotations of the joints. Joints will be denoted by single suffices running from $n=1$ to $n=N$, if N is the total number of joints in the framework. Bars will be denoted by double suffices indicating the two joints which are connected by the bar. Correspondingly e_{mn} is the extension FL/EA of the bar between joints m and n, and ϕ_m is the rotation of the mth joint from its original position. It will be assumed that the influence of the bending moments in the bars upon the axial forces can be neglected. This assumption is usually made in similar calculations in order to avoid too great complications, it is underlying the moment distribution procedure of Hardy Cross, and is well allowable when dealing with the side panel of an aeroplane, or with similar frameworks.

On this understanding it is allowable to devise the following loading procedure. First, the external forces alone are applied and the truss is assumed to have perfect frictionless pin-joints throughout. External moments acting upon the joints should be replaced in this stage of calculations by a statically equivalent system of forces acting at the joints. Since there exists an infinite number of such statically equivalent systems, it is suggested to distribute the bending moment between the bars common to the joint where it is acting in the ratio of the stiffnesses S of the bars.

If in such a structure the elongation of bar mn is increased by the amount δe_{mn}, the work done by all external loads during the ensuing displacements of the framework is equal to the product of the axial force in the bar mn into δe_{mn}. From this condition the axial forces in the bars can be calculated. The same values of the forces are obtained if determined by a reciprocal diagram.

After the truss has deformed under these conditions, rigid connection between the bars is established. By this loading procedure the so-called secondary stresses in the bars have been eliminated. The specified external moments are then applied at the joints. The work done by the end moments of all the bars in the framework during the ensuing rotation of all joints can be written with the aid of Eqs. (5) as

$$U_M=(1/4)\sum_{m=1}^{N}\sum_{n=1}^{N}K_{mn}\left[\mu_{mn}\left(\phi_m{}^2+\phi_n{}^2\right)+\mu'_{mn}\,2\,\phi_m\phi_n\right] \quad . \quad . \quad (23)$$

where (1/4) stands rather than (1/2) since every bar appears twice in the double summation, and where K_{pq} must be put zero if there is no bar to connect the pth with the qth joint. The work done by the external moments during a virtual rotation is

$$\delta W=\sum_{n=1}^{N}M_n\phi_n$$

whence the potential of the external moments

$$V_M = \sum_{n=1}^{N} M_n \phi_n \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

The strain energy stored in the bars consists of U_M plus the work done by the end loads acting on the bars during the shortening of the bars due to the curvature caused by the end moments. In a single bar this part of the strain energy is in general of the same order of magnitude as that due to the end moments, but when summed up for the whole framework it is generally small, since its sign is positive for bars in compression and negative for bars in tension. Furthermore, the change of this part of the strain energy during a virtual rotation $\delta\phi_n$ is equal to the work done by the external forces (but not the moments) during the displacements of their points of application due to the shortenings of the bars caused by the change of curvature due to $\delta\phi_n$. This must be so, since the magnitude of the axial forces in the bars has been determined from an analogous set of equations, as stated earlier in this section. These terms, therefore, cancel out in the expression of the change of the total potential energy $\delta(U-V)$. Therefore, the only terms in the expression of the total potential energy which are of interest for the present purposes can be written

$$(U-V) = (1/4) \sum_{m=1}^{N} \sum_{n=1}^{N} K_{mn} \left[\mu_{mn} (\phi_m^2 + \phi_n^2) + \mu'_{mn} \, 2 \, \phi_m \phi_n \right] - \sum_{n=1}^{N} M_n \phi_n \, . \quad (25)$$

In this equation the expression under the double summation representing the strain energy is a quadratic form in the ϕ the discriminant of which is

$$D = \begin{vmatrix} \sum_{1} K_{1n}\mu_{1n} & K_{12}\mu'_{12} & K_{13}\mu'_{13} & \cdots & K_{1N}\mu'_{1N} \\ K_{21}\mu'_{21} & \sum_{2} K_{2n}\mu_{2n} & K_{23}\mu'_{23} & \cdots & K_{2N}\mu'_{2N} \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ K_{N1}\mu'_{N1} & K_{N2}\mu'_{N2} & K_{N3}\mu'_{N3} & \cdots & \sum_{N} K_{Nn}\mu_{Nn} \end{vmatrix} . \quad (26)$$

In this determinant the digit below the sign of summation indicates that the summation extends over all bars common to the respective joint.

By the principle of virtual displacements the condition of equilibrium is

$$\delta(U-V) = \frac{\partial(U-V)}{\partial\phi_1}\delta\phi_1 + \frac{\partial(U-V)}{\partial\phi_2}\delta\phi_2 + \cdots + \frac{\partial(U-V)}{\partial\phi_N}\delta\phi_N = 0 \quad (27)$$

which must be fulfilled for any set of changes $\delta\phi_n$ of the rotations. Therefore, N independent equations are obtained, the first of which is

$$\frac{\partial U}{\partial\phi_1}\delta\phi_1 - M_1\delta\phi_1 = 0,$$

that is

$$\phi_1 \sum K_{1n}\mu_{1n} + \phi_2 K_{12}\mu'_{12} + \phi_3 K_{13}\mu'_{13} + \cdots + \phi_N K_{1N}\mu'_{1N} - M_1 = 0 \quad . \quad (28)$$

The denominator determinant of these N linear equations is identical with D in Eq. (26).

The second order small increment $(1/2)\,\delta^2(U-V)$ is a quadratic form in the $\delta\phi$:—

$$\left.\begin{aligned} \delta^2(U-V) = {} & \frac{\partial^2(U-V)}{\partial\phi_1^2}(\delta\phi_1)^2 + \frac{\partial^2(U-V)}{\partial\phi_1\partial\phi_2}\delta\phi_1\delta\phi_2 + \cdots + \frac{\partial^2(U-V)}{\partial\phi_1\partial\phi_N}\delta\phi_1\delta\phi_N \\ & + \frac{\partial^2(U-V)}{\partial\phi_2\partial\phi_1}\delta\phi_2\delta\phi_1 + \frac{\partial^2(U-V)}{\partial\phi_2^2}(\delta\phi_2)^2 + \cdots + \frac{\partial^2(U-V)}{\partial\phi_2\partial\phi_N}\delta\phi_2\delta\phi_N \\ & + \cdots + \frac{\partial^2(U-V)}{\partial\phi_N\partial\phi_1}\delta\phi_N\delta\phi_1 + \frac{\partial^2(U-V)}{\partial\phi_N\partial\phi_2}\delta\phi_N\delta\phi_2 + \cdots + \frac{\partial^2(U-V)}{\partial\phi_N^2}(\delta\phi_N)^2 \end{aligned}\right\} \quad (29)$$

Its discriminant is again the same as D in Eq. (26).

If the total potential energy is represented as a second order surface in the $N+1$ dimensional space and the vertical axis is taken to represent $(U-V)$ then the condition of a stationary value of $(U-V)$, that is of a horizontal tangent plane to the surface, is given by Eq. (27). The values of the rotations ϕ_n can be computed from the set of linear equations (28). This stationary value is a minimum only if the second order small change of $(U-V)$ is positive for any choice of the changes of the rotations, and zero only if every ϕ_n is equal to zero. This is the condition for a positive definite quadratic form which obtains if D and every minor of it which can be arrived at by successively deleting the last rows and columns is positive.

As long as the quadratic form representing the strain energy is positive definite, therefore, the total potential energy surface has a minimum and the equilibrium is stable. The values of the rotations ϕ_n corresponding to this equilibrium can be obtained from a set of linear equations, the denominator determinant of which does not vanish. Consequently there exists one, and only one, solution which corresponds to the origin only if all external moments are simultaneously equal to zero. Thus equilibrium in the framework under a specified system of external moments can be obtained for only one shape of the distortions which result agrees with Kirchhoff's theorem of the uniqueness of the solution. In such a case, by Theorem 3 and the reasoning given in Sec. the only state of distortions for which the equations of equilibrium are fulf... can be reached by a sufficiently large number of steps of the Cross method.

Negative definite forms for the strain energy are not considered in the present paper since the terms on the principal diagonal of the discriminant have been assumed positive. Indefinite forms, however, are possible and correspond to a saddle point of the surface. In such a case the equilibrium is unstable and the Cross method, in general, does not yield finite results. This, together with the possibility of an exceptional case, has been shown in Sec. 3. It is of theoretical interest, however, to mention that the saddle point can be reached by the Cross method if some of the partial systems are unstable ($\Sigma S < 0$). In an unstable partial system, namely, the total potential energy increases when the joint is allowed to rotate and attains the maximum compatible with the fixed values of the rotations of the other joints.

The critical, or limiting case between stability and instability corresponds to $D=0$. This means that the equations of equilibrium Eqs. (28) are interdependent, that is the rank of their matrix is reduced which corresponds to a degenerated $(U-V)$ surface. The homogeneous equations which can be obtained by cancelling the external moments in Eqs. (28) admit an infinite number of solutions. The inhomogeneous equations, however, cannot be solved for an arbitrary set of external moments and in such cases, therefore, the steps of the Cross method cannot approach equilibrium. However, for particular values of the external moments the inhomogeneous equations can be solved and for such a set of external moments an infinite number of solutions exists.

Incidentally, it is interesting to show that the work done by the external moments from the unstrained state to the distorted state corresponding to the stationary value of the total potential energy, is equal to the strain energy stored in the framework, that is the principle of conservation of energy is satisfied. In fact, the work done by the external moments during the rotations of the joints equals one-half the sum of the products of the moments by the corresponding rotations. Multiplying the moment M_1 (calculated from Eq. (28)) by ϕ_1 the following result is obtained:—

$$\phi_1 M_1 = \phi_1^2 \sum_1 K_{1n}\mu_{1n} + \phi_1\phi_2 K_{12}\mu'_{12} + \phi_1\phi_3 K_{13}\mu'_{13} + \cdots + \phi_1\phi_N K_{1N}\mu'_{1N} \quad (30)$$

By adding to the above expression the corresponding expressions for

$\phi_2 M_2$, $\phi_3 M_3$, . . . $\phi_N M_N$, and multiplying the sum by (1/2) the strain energy is obtained, as given in the first term of Eq. (25).

Finally, it should be mentioned that the choice of the values of the modulus of elasticity in $K=EI/L$ presents difficulties if the stresses exceed the elastic limit. In cases when all external forces are applied at joints and the moment distribution method is used only to check the stability upon the assumption of a " dummy " moment at one of the joints, von Kármán's effective (reduced, or double-) modulus* corresponds well to actual conditions. If, however, the bending stresses caused by lateral loads cannot be considered as small, the effective modulus is but a first approximation. A more detailed investigation of this effect by a step-by-step process is possible but very laborious.†

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* See Ref. 7, also Refs. 3, 11 and 20.

† Author wants to give expression to his belief that similar considerations could also be proffered in the case of Professor Southwell's method of systematic relaxation of constraints (see Ref. 17) of which unfortunately he has too little knowledge to feel able to make any more positive statement.

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THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES

AUGUST, 1941.

Discussions.

The Council have decided that, in spite of the difficulties of war conditions, an endeavour should be made to maintain active interest in technical aeronautics among the entire membership of the Society. It is intended to hold discussions on some or all of the following subjects in the near future. Members of the Society are invited to inform the Secretary which discussion or discussions they would like to attend. It is proposed to hold the discussions on Sundays at the most suitable place in London or the country, depending upon the replies received. Discussions will only be held on those subjects, which, from the replies received, are shown to be of interest to a number of members.

These discussions will be open to all grades of the Society and, to satisfy the needs of security and safety, it will be necessary for those who wish to attend any particular meeting, to notify the Secretary as quickly as possible, so that arrangements can be made for the exact date and place of the meeting.

It must clearly be understood that no one will be allowed to attend the meeting who has not notified the Secretary in advance, and no notice will be given in the Journal of the time or place of the meeting.

When a discussion has been arranged, members who have indicated their interest in that particular discussion will be notified.

The following is a list of proposed subjects. Each subject is followed by the names of speakers who have undertaken to help in the discussion:—

(*a*) Drawing Office Methods.	Mr. S. Camm, F.R.Ae.S. Mr. M. Langley, F.R.Ae.S.
(*b*) Application and Correlation of Wind Tunnel and Full-Scale Testing.	Mr. D. L. Ellis, A.F.R.Ae.S. Mr. R. H. Francis.
(*c*) Vibration Problems.	Dr. A. G. Pugsley, A.F.R.Ae.S. Dr. Ker Wilson.
(*d*) Tolerances, Limits and Inspection.	Mr. L. G. Fairhurst.
(*e*) Drag Reduction.	Mr. W. G. A. Perring, A.F.R.Ae.S. Mr. R. L. Lickley, A.F.R.Ae.S.
(*f*) Control Surface Design.	Mr. R. T. Youngman, F.R.Ae.S. Mr. H. B. Irving, F.R.Ae.S.
(*g*) The Future of Civil Aviation.	Dr. H. Roxbee Cox, F.R.Ae.S. Mr. W. L. Runciman.

The Council will appreciate suggestions for further subjects from members of the Society.

Election of Members.

Associate Fellows.—William Armstrong (from Student), Lionel Hubert Charles Cranfield (from Student), Clifford Leslie Moon (from Student).

Associates.—William Edward Sedgwick, Herbert Stansfield, Fred Brooks Stott.

Graduates.—John Allan, Jacob Lionel Bakst Cooper, Brian Ruckman Hutchinson (from Student), Wilfred Morris, Leslie George Toms.

Students.—Sidney Andrew Kenneth Bennett, Kenneth Nestor Brown, George Cordrey, Kenneth Arthur Jordan, Francis Nicholas Kirk, Davis Rees Martin, Eric Louis Pariser, Stanley Clifford Warner.

Companions.—Leslie Francis Graves Badham, Gilbert Edward Isaac Clements, Wilfred George Frederick Codling, Frederick Hugh Fleck, Arthur Hillier, Felix James Samuely.

Air Training Corps.

The following letter has been received from Air Commodore Chamier.

July 1st, 1941.

Dear Sir,

I have no doubt that many of the members of your Society are assisting units of the Air Training Corps as individuals. I now write to ask you whether they cannot help the Headquarters of the A.T.C. in the following manner.

2. Whereas the compulsory course which our cadets have to go through is of a simple nature and could be conducted in almost any village in the Kingdom, it does not provide the aviation knowledge and interest which the cadets come to the Corps to acquire. We are anxious to use every possible means by which aviation can be brought to the ground, so to speak, for study by these many hundreds and thousands of young men. One of these difficulties is that these young men are grouped into something over 1,300 separate units, and it is hardly possible to conceive of issues of films and projectors and lantern slides in sufficient quantities to demonstrate *e.g.* the principles of airflow. What we need is something which can be home made, so to speak, by the units themselves, who have much light engineering capacity at their command; a simplified form of Mr. Farren's or Herr Lippisch's smoke tunnels, working models which can be shown either three dimensionally or on epidiascopes; anything which may interest and instruct in any branch of aviation, would be welcomed.

3. I have in mind that I once saw in a French paper a suggestion that a simple apparatus could be produced under which air compressed into a tank was used to blow a jet against a model aeroplane wing; a small leak from the same tank produced every three seconds or so an air inflated soap bubble in front of the jet; this was blown downstream and made the airflow visible; the bubble constantly renewed itself automatically as long as compressed air remained and the jet was flowing.

4. If any of your members have experimented with anything of this kind, I should be grateful for any possible information at the earliest moment, and if the models were for example sliding on a rod like certain motor car radiator models, then with the increase in air speed or angle of incidence the model could be shown to rise, thereby indicating the increase of lift; at a further angle of incidence the stall could be demonstrated.

5. I cannot stress too highly the interest value of some apparatus of this kind or any other kind that may occur to your members in the training

of our young men. You will realise that we only want to demonstrate principles and not make accurate quantitive measurements.

Yours faithfully,

J. A. CHAMIER, Air Commodore,
Commandant, Air Training Corps.

The Secretary,
Royal Aeronautical Society,
4, Hamilton Place, London, W.1.

Acknowledgments.

The Council acknowledge with grateful thanks the gift of a copy of the Report of the Bird Construction Committee, 1911, from the President, Mr. Griffith Brewer.

Birthday Honours.

C.B.—Acting Air Vice-Marshall R. M. Hill, M.C., A.F.C., Fellow.
C.B.E.—Wing Commander T. N. McEvoy, Associate Fellow.
A.F.C.—Flt. Lt. R. E. Drake, Associate Fellow.

Additions to the Library.

Pamphlets in italics, with location reference following in brackets.
Books marked * may not be taken out on loan.

A.a.238.—The Elements of Aeronautics. By K. Schütt. Sir Isaac Pitman. 1941. 12/6.

A.a.239.—*Isotropic Turbulence in Theory and Experiment. By Hugh L. Dryden. Reprint from "Applied Mechanics," Th. v. Kármán, Anniversary Volume,* 1941. (Y.1.a.17.)

B.a.233.—History of the Development of Torpedo Aircraft. (A.P.1344). Air Ministry, 1919.

*BB.b.90.—Airworthiness Handbook for Civil Aircraft. (A.P.1208.) Provisional Edition, Sept. 1936. H.M.S.O. 1937. 6/-.

*BB.c.72.—*Rotol Variable Pitch Airscrews: Their Construction and Operation. (Book No.* 19.) Rotol Airscrews, Ltd. 1941. (PBB.2.b.9.)

*BB.c.77.—Rotol No. 6 size Electrically Operated Airscrews. (Series RE.6.) (Book No. R.5.) 1940.

*BB.c.78.—Rotol Nos. 4 and 5 Series Hydraulically Operated Airscrews. (Series R4 and R5.) (Book No. R.6.) 1940.

*BB.c.79.—Rotol Nos. 5 and 6 size Hydraulically Operated Airscrews. (Series RX5, RXF5, RS5, RSF5, RS6, RSF6.) (Book No. R.13.)

F.b.33.—*Aviation Fuels of High Octane Number. By D. A. C. Dewdney and A. R. Ogston. Reprint from "Intava World," Oct.,* 1940. (Y.7c.13.)

*G.b.36.—*List of British Standards (including A.R.P. Standards). British Standards Institution.* 1941. (PG.2/15.)

H.a.10.—*Hardship and Military Service. By Ralph G. Yablon. Hamish Hamilton. 6d.* (PH.1.a.2.)

L.e.7.—How the British Admiralty Charts are Produced. Admiralty Chart Agency (Potter). 1934.

L.e.8.—British Admiralty Charts: their Use and Correction. Admiralty Chart Agency (Potter). 1936.

*S.b.103.—A.B.C. of the R.A.F. Ed. by Sir John Hammerton. Amalgamated Press, Ltd. 1941. 2/-.

T.a.88.—The Red Knight of Germany (Von Richthofen). By Floyd Gibbons. Cassell & Co., 1930.

TT.b.14.—Flying over London (and other Verses). By Lynn H. Hough. Abingdon Press (U.S.A.), 1919.

UL.6.—*Aeronautical Research Institute, Tokyo: Reports:—*

No. 204. Numerical Calculation of Power Variation with Altitude in a naturally aspirated Engine by means of J.S. Diagrams. By K. Tanaka, O. Tamura and O. Konisi. 1941.

No. 205. On the Subsonic Flow of a Compressible Fluid past a symmetrical Jiukowski Airfoil. By S. Tomotika and H. Umemoto. 1941.

*UU.c.—*National Advisory Committee for Aeronautics: Technical Memoranda:—*

No. 969. Experiences with Flow-Direction Instruments. By B. Eckert. (From: Jahrbuch der Deutschen Luftfahrtforschung, 1938.)

No. 970. Experimental Investigations on Freely Exposed Ducted Radiators. By W. Linke. (From Jahrbuch der Deutschen Luftfahrtforschung, 1938.)

No. 971. The Elliptic Wing based on the Potential Theory. By K. Krienes. (From Z.A.M.M., April 1940.)

No. 972. Use of Charts for Flow Discharge Calculations. By O. Lutz. (From Luftfahrtforschung, Oct. 1940.)

No. 973. Potential Flow through Centrifugal Pumps and Turbines. By E. Sörensen. (From Z.A.M.M., April 1927.)

No. 975. The Efficiency of Combustion Turbines with Constant-Pressure Combustion. By W. Piening. (From Luftfahrtforschung, Sept. 1940.)

*X.e.46.—Ledamotsförteckning. (Members' List.) Svenska Teknologföreningen. 1941. Kr.3.50.

J. Laurence Pritchard, *Secretary and Editor.*

THE PROPELLER.

HOW MANY BLADES?

By F. W. Lanchester, LL.D., F.R.S., Hon. F.R.Ae.S.

Propeller theory has always been a subject of extreme difficulty, and those who originated the screw propeller as a means of propulsion and developed it during the latter half of last century were in most part guided by common sense and empiricism. Without much in the way of theory to guide them the results thus achieved in connection with marine propulsion were remarkable—but little short of the best possible. The designers of the early experimental aircraft were able to make use of the wealth of experience thus placed at their disposal; nevertheless, some new aspects of the problem presented themselves—fortunately the vortex theory, newly developed to deal with the problem of sustentation in flight came to their aid, though the manner of its application was not obvious or easy. The writer's first attempt* consisted in treating the propeller blade as an aerofoil connected to the boss by an arm of spar section, geometrically related to a helical surface, in which the tracks of the blades relatively to the fluid follow these surfaces. If these tracks are in too close proximity, the individual blades will not find sufficient fluid on which to operate without interference, and if they are too far apart the propeller will not be adapted to take full advantage of the fluid coming within its grasp. This is common sense. It is just this matter of *proximity* which determines the number of blades which may be advantageously employed.

This aspect of the subject was treated more fully in a paper read by the writer before the Institution of Automobile Engineers in 1915.

According to the vortex theory, although there is no special limit to the dynamic disturbance produced by an aerofoil or a propeller blade in its passage, it is possible to express the equivalent quantity of fluid dealt with as that which would be contained in or circumscribed by a cylindrical surface whose diameter is equal to the span in the case of an aerofoil, or to the blade length in the case of a propeller—*acted on equally.*† It is on this basis that the work done in sustentation may be calculated, and is thus at the foundation of the dynamics of the aeroplane.

The method adopted by the writer in his 1915 paper, is based on the conception that each blade requires a quantity of fluid on which to operate defined in just this manner, so that if we consider a rope as representing the fluid dealt with by the propeller each strand of that rope will have a diameter equal to that of the blade length. Then as the number of strands will depend upon the angle at which they are laid, in like manner will depend the number of blades which they represent. This is not quite exact, but as an explanation it may be allowed to pass.

Now the whole length of the blade is not effective, and as a convention the writer took the outer three-quarters of its length to be effective and the central

* "Aerial Flight" Vol. i, "Aerodynamics" (Lanchester) Chap. IX.

† Proc. I.A.E., Vol. IX, Fig. 17, p. 200. Also Journal R.Ae.Soc., Vol. XXX, pp. 600 *et seq.* and Vol. VLI, pp. 83 *et seq.*

quarter to function merely as a means of attachment to the boss.* In Figs. 1 and 2, this is suggested by the " core " of the rope on which the strands are centred being shown about one quarter of the outside diameter.

In the investigation in question the aspect ratio of the blade was assumed $\mathbf{n}=6$, which would give a maximum blade width equal to one sixteenth of the propeller diameter. For an aeronautical propeller this is fairly representative. For a marine propeller the aspect ratio is far less, the blade width being commonly about one sixth of the diameter or less, giving $\mathbf{n}=2$ or thereabouts, or in the case of propellers for fast going craft (above the cavitation limit) $\mathbf{n}=$(more nearly) 1 the blade being almost a circular disc. The reason (between aeronautical and marine practice) for this difference is mainly the need for greater strength in the marine type.

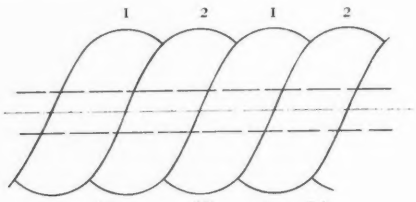

FIG. 1. (*Two strand.*)

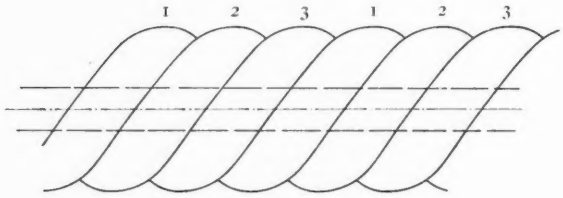

FIG. 2. (*Three strand.*)

In the present article the results of the previous investigation will be assumed without discussion; these results, shown as a diagram (Fig. 23 in the I.A.E. Proceedings) are here summarised in the form of a table. It will be seen that in a propeller of quick pitch, *i.e.*, high P/D ratio there is room for a fourth blade, since three blades do not take full advantage of the whole race area. For this reason, for a given P/D ratio, the three-bladed propeller needs to be of greater diameter than that of four blades, and a two-bladed propeller is of still greater diameter. This is typically illustrated at the head of the table by the entries relating to a P/D ratio$=1.46$. It is less true in the case of the entries relating to $P/D=1.3$ and less still in the case of $P/D=1.2$. When the P/D ratio is 1.1 the advantage of the fourth blade is practically gone, no perceptible gain in the direction of a reduction in the diameter results, and the added skin-friction or so-called " profile drag " can only result in a loss of efficiency. It is doubtful whether it would be profitable to make use of four blades in any propeller having a P/D ratio less than 1.25 and only then if the limit as to diameter needs to be strictly observed. At the other end of the scale it will be seen that for a P/D ratio$=0.7$ there is but little advantage of a three-bladed propeller over one of two blades and for $P/D=0.6$ none whatever. For $P/D=0.5$ even two blades give rise to some interference or periptory overlap, and figures are given in the table for a single blade (in brackets), although of course this does not represent a practical solution.

* Compare " Aerodynamics," Fig. 133, p. 315.

EFFICIENCY.

The theoretical efficiency given in column (5) takes no account of the portion of the blade connecting the blade proper to the boss, nor of skin-friction or drag due to the boss itself. The writer has computed this as involving a reduction in the efficiency of the order of 10 per cent. and the figures given in column 6*b* are based on this estimate. In the writer's opinion the designer and constructor would be doing reasonably well if under the most favourable conditions these figures could be reached. If the blade tip speed through the air were to approach the velocity of sound the efficiency would be considerably reduced; the extent of any such reduction could only be ascertained with precision by actual experiment. Again,, as pointed out, the introduction of a fourth blade, or one extra blade when there is not proper room for it can only be detrimental to efficiency.

The two-bladed propeller suffers from one grave disadvantage, namely, it sets up considerable vibration when the aeroplane is making a turn or otherwise on a curvilinear course as when diving or "zooming." This became known as a practical fact early in the history of aviation. By some it was attributed to gyroscopic action, but the writer did not so regard it; in his view the gyroscopic couple was the same and constant for any given angular momentum of the rotating body if the rate of turning be given. When turning the vibration can be traced to a variation in the moment of inertia of the propeller *about a vertical axis*. When in plan view the propeller appears as extended, the moment of inertia is greatest, when in a position at right angles so that the blades are viewed end on, the moment of inertia is least. If the propeller were not rotating but were represented by two massive knobs approaching and receding from the axis, the same would be true; when the knobs were farthest apart the moment of inertia would be greatest and when coincident least. Analysis shows that in a two-bladed propeller the gyroscopic moment has superposed on it a moment fluctuating harmonically whose maximum is equal to that due to gyroscopic action, so that the resultant varies from zero to twice that due to gyroscopic action alone. This is as given in R. and M. 185, p. 275, Adv. Comm. Aeronautics, 1914-15 (F. W. Lanchester and B. Melville Jones). To-day there is a strong tendency to discard the "two-blader" altogether.

It is well to call attention here to the fact that *pitch*, denoted by the symbol P, is in the author's theory the effective pitch, that is the flight velocity divided by the revolution speed, and *not* the geometrical pitch as postulated by naval architects. This seems inevitable in view of the fact that the effective pitch is *definite*. For any given condition it is the velocity divided by the revolution speed, as for example if the former be 300 ft./sec. and the latter 30 revs. per sec. the *effective* pitch $P=10$ ft. It is true that if the same propeller be used under other conditions the effective pitch may be different, but that only means that the propeller is not being used under the conditions for which it was designed. The geometrical pitch is quite definite only if the form of the blade is a true helix, as was commonly the case in the early days of marine propulsion; in a propeller designed in accordance with the writer's prescription (see "Aerodynamics," Ch. IX), the geometrical pitch varies from point to point. Fig. 3 is taken from the reference given (p. 328, Fig. 139) as representing a suitable design for the conditions specified, blade sections being given in Fig. 137.

In order to apply the data given in the table, it is necessary, for some definite P/D ratio, to make use of an expression giving the thrust in terms of the propeller diameter and the flight velocity. The form of this expression is evidently

$$F=\frac{V^2D^2\rho}{k}$$

in which V is the velocity of flight, D is the propeller diameter, and ρ the density of the air, k being a constant. F is the thrust.

If we take the optimum as the datum, when $P/D=1.46$; then using British abs. units (V=ft./sec., D=ft., ρ=lbs. mass per cu. ft.) if F the thrust be

TABLE.

THE SCREW PROPELLER.

1	2	3	4	5	6	7
					Efficiency.	
P/D	No. of Blades.	$D/D!$	$P/D!$	$P/P!$	Theoretical.	Probable limit.
1.46	4	1.00	1.46	1.00	0.860	78%
	3	1.16	1.69	1.15		
	2	1.41	2.05	1.40		
1.3	4	0.86	1.12	0.77	0.859	78%
	3	0.93	1.21	0.83		
	2	1.14	1.48	1.02		
1.2	4	0.77	0.925	0.63	0.855	77%
	3	0.80	0.96	0.66		
	2	1.01	1.20	0.82		
1.1	4	0.72	0.79	0.54	0.850	76%
	3	0.73	0.80	0.55		
	2	0.92	1.01	0.69		
1.0	4	—	—	—	0.840	75%
	3	0.66	0.66	0.45		
	2	0.83	0.83	0.57		
0.9	4	—	—	—	0.830	74%
	3	0.60	0.54	0.37		
	2	0.74	0.67	0.46		
0.8	4	—	—	—	0.815	73%
	3	0.56	0.45	0.31		
	2	0.65	0.52	0.36		
0.7	4	—	—	—	0.800	71%
	3	0.45	0.315	0.22		
	2	0.48	0.335	0.23		
0.6	4	—	—	—	0.760	69%
	3	—	—	—		
	2	0.42	0.25	1.17		
0.5	3	—	—	—	0.720	65%
	2	0.36	0.18	0.125		
	(1)	(0.48)	(0.25)	—		

Column (1) The pitch/diameter ratio is given. On this the efficiency values in Cols. (6) and (7) depend.

,, (2) Gives the number of blades.

,, (3) Gives the appropriate diameter in terms of "D optimum" symbol $!D$, or $D!$.

,, (4) Gives the appropriate pitch in terms of $!D$.

,, (5) Gives the appropriate pitch in terms of $!P$.

,, (6) Gives the theoretical efficiency as computed, as dependent upon the P/D ratio; it is a maximum value based on the assumption that the blades are not overcrowded.

,, (7) Gives the probable maximum efficiency when allowance has been made for unavoidable losses. Actual test results could scarcely be expected to exceed this figure.

NOTE.—The "optimum" condition is when the pitch diameter ratio, namely, $(!P)/(!D)=1.46$, and the optimum value of D (symbolised by $!D$) is taken as datum and assigned unit value. The optimum value of pitch (denoted by the symbol $!P$) $=1.46$. When there is a limit set to the diameter it is desirable to make the fullest possible use of the slip stream, and, to this end, specify the maximum number of blades; but when as with $P/D=1.2$ or 1.1 the addition of a fourth blade makes but little difference to the diameter, that is to say gives but little relief in that direction, it denotes that there is interference or overlap and a consequent loss of efficiency. The writer would make the reservation that strictly speaking the theory is based on a restriction of diameter, and though the table may be applied to restrictions of other kinds—for example pitch and revolution speed, with the diameter as consequent—the result must be considered more in the light of an approximation than as a complete solution. Also if a propeller be operated at a thrust lesser or greater than that specified the efficiency will be less, although for small variation this may be ignored.

expressed in poundals, we have by a computation into which it is not necessary here to enter, $k=44$, or, for those who cannot make friends with the poundal,

$$F \text{ (pounds)} = \frac{V^2 D^2 \rho}{1400} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a)$$

or, F being given,

$$D = \sqrt{\frac{1400\, F}{V^2 \rho}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1b)$$

If the conditions are such that the optimum propeller may be adopted, nothing further is necessary, but more often than not the diameter $!D$ may be greater than permissible, or the pitch ($1.46\, D$), taken in conjunction with V, may imply a revolution speed other than that for which an engine is available. It is then that, from the table, a selection must be made to conform as closely as possible to the conditions. This is best illustrated by aid of a few hypothetical examples. In this the values of V and ρ taken are those representing the conditions when the *best* results are wanted, but it may be noted that as these two symbols appear together in the form $V^2\rho$ a change of velocity may be compensated by a change in altitude.

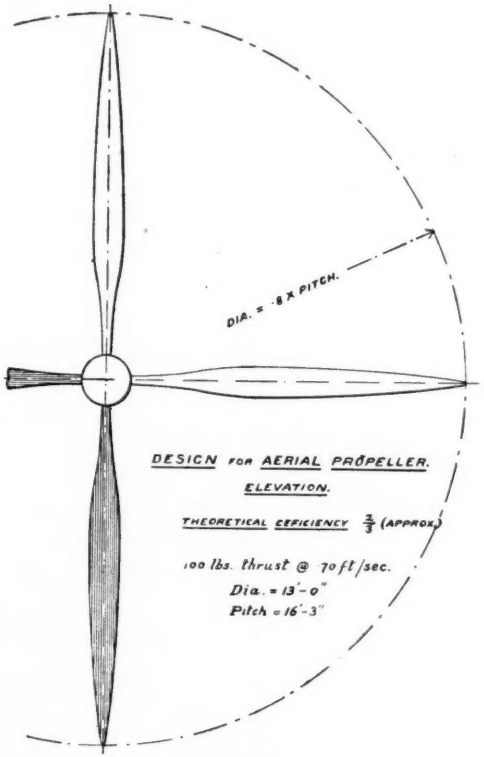

FIG. 3.

PROCEDURE IN THE USE OF TABLE.

Before taking actual cases we may assume that the optimum diameter $!D$ has been ascertained by an application of equation ($1b$) from data given. Then if there be a diameter limit less than this $=D$ the value of $D/!D$ is known and this value is sought in column 3. Thence reading horizontally the appropriate

P/D ratio is read off in Col. (1) and the number of blades in column (2). There is usually some choice and it is desirable when possible to select a three- or four-bladed propeller; but generally when the difference in Col. (3) and (4) between three and four blades is small it denotes interference. With P/D greater than 1.2 usually a fourth blade is permissible, but not otherwise. *It is to be remembered that all propellers specified in the table are capable of carrying the same thrust for given value of* $!D$. In Cols. (4) and (5) the pitch is given in terms of $!D$ and $!P$ respectively, the relation being 1.46. When the effective pitch, settled by the velocity of flight V and the revolution speed, forms part of the initial specification and the P/D ratio is known the value of $!D$ is derived at once from Col. (4) or that of $!P$ from Col. (5).

The theoretical efficiencies given in Col. (6) are based on the conventional assumption that there are no losses due to structural considerations (*i.e.*, blade supports or central boss). The expressions in Col. (7) have been taxed to the extent of 10 per cent. to allow for such losses. But no allowance has been made to compensate for interference (additional skin friction) when the blades are overcrowded, that is if four blades are provided where three are sufficient, or three in place of two.

EXAMPLES.

(1) It is assumed that the problem set to a designer is that of specifying a propeller not to exceed some stated diameter for some definite flight speed, the engine speed of revolution being given. We will assume that the plane will have a gross weight of five tons to be propelled by twin engines, one of which alone must be capable of maintaining the plane in flight. Let the diameter limit be 8 ft. and the prescribed flight speed 320 ft./sec. Let engine speed be 2,400 r.p.m. = 40 revs. per sec. Then the effective pitch $= 320/40 = 8$ ft.

If now we assume the maximum diameter as the optimum $D!$ then the pitch would be $P! = 1.46 \times 8 = 11.7$ ft. instead of 8 ft. as above. That is the pitch required is $8/11.7$ of the optimum $= 0.685$. Consulting the table Col. (5) this suggests a three-bladed propeller having a P/D ratio 1.2, the diameter being 0.80 of optimum, namely, $D = 6.4$ ft. and $P = 7.7$ ft.

On this a trial computation of the thrust F may be made.

$$F = \frac{64 \times 102{,}000}{1{,}400 \times 13} = 360 \text{ pounds.}$$

Now if a machine of 11,000 lbs. weight is to be flown by one propeller only, that is with one motor disabled, the thrust F will need to be in the region of 800 pounds. This means that a new choice must be made of the optimum diameter. Let it be taken as 11 ft. Then,

$$F = \frac{121 \times 102{,}000}{1{,}400 \times 13} = 790 \text{ pounds,}$$

which is satisfactory.* But this is the optimum, and the pitch is $11 \times 1.46 = 16.1$ instead of 8 ft., this must be corrected by choosing a propeller, Col. (5), whose pitch factor is $8/16 = 0.5$.

Referring to the table, this suggests a three-bladed propeller having a P/D ratio 1.1 or perhaps unity. In the former case the diameter D will be $0.73 \times 11 = 8.03$ ft. which is but little in excess of the 8 ft. limit. The pitch will be $1.1 \times 8.03 = 8.8$ ft. Taking the latter the diameter will be $0.66 \times 11 = 7.26$ ft., which is well within the limit. The P/D ratio being unity in this case the pitch is also 7.26 ft., which is that desired. The efficiency Column (7) is three or four per cent. less than the optimum; that is, the tax paid for the restriction of the diameter, one of the conditions postulated. We shall not be

* The atmospheric density represented by the symbol o is taken as at sea level. One cubic foot $= 1/13$ of a pound mass.

far wrong if we take the P/D ratio required as 1.05 with $D=7$ ft. 8 in. and $P=8$ ft. 0 in.

(2) In the writer's "Aerodynamics," Chap X, Fig. 139, p. 328, an outline design of a four-bladed propeller is given, of which particulars are as follows:— Diameter, 13 ft.; pitch, 16.25 ft.; flight velocity, $V=70$ ft./sec.; and F (thrust), 100 pounds. This was based on the general aerofoil theory then under discussion; it is of interest to examine this example in the light of the later development of the theory. Accepting the check on the diameter, other data as given will alone be considered. Employing expression (1*b*) we must first derive $D!$, thus $D!=\sqrt{(1{,}400\,F/V^2\rho)}=\sqrt{(140{,}000/380)}=19.2$ ft. optimum diameter, giving $P!=19.2\times1.46=28$ ft. Since 16.25 is the specified pitch, the pitch factor in the table Col. (5) is $16.25/28=0.58$, which corresponds to a P/D ratio, $=1.15$ (for a propeller of four blades) the D factor (Col. (3)) may be taken as 0.73 and the necessary diameter approximately 14 ft. as against 13 ft. as given. This may be taken as a measure of the difference between the theory as originally presented in 1907 and as now given.

(3) A Further Example, an Extreme Case.

The Voisin aeroplane, designed by M. Colliex, as flown by M. Farman, was fitted with a single two-bladed screw, of something over two metres diameter, and a P/D ratio 0.5, exact particulars are wanting as several propellers were tried in which both pitch and diameter differed. We shall take it that $D=7.5$ ft. and $P=3.75$ ft. The engine was an Antoinette rated to give 49 b.h.p. at 1,100 r.p.m. The engine was certainly run at a higher speed when in full flight; we shall take it that the normal output was 50 b.h.p. at 1,400 r.p.m. or 23.5 r.p.s., leaving a margin of power for use in ascending or for contingencies.

The above $V=23.5\times3.75=88$ ft./sec. This (=60 m.p.h.) is higher than usually credited, but it is difficult to reconcile data on any other basis.

$$!D=7.5/0.36=20.8 \text{ ft.} \quad \therefore \quad F=(430\times7{,}700)/(1{,}400\times13)=182 \text{ pounds.}$$

This is lower than that estimated as necessary, but the blade aspect ratio was less, more nearly 4 than 6, which latter is the basis of the theoretical values tabulated. This will give a greater area in the ratio of 4 to 6, but a less pressure value in the relation of 4.05 to 3.38,* the net increase being:—

$$(6/4)\times(3.38/4.05)=1.25 \text{ giving } =228 \text{ pounds.}$$

Perhaps this allowance is too great. The aspect ratio may have been as much as 5 in which case the increase is only 10 per cent. giving 200 pounds. On this footing the agreement is almost too good to be true, in view of the doubts that exist as to the original data. Mr. Colliex was very frank and did not attempt to hold back any information that he was able to give, but there was much that he could only give to a rough degree of approximation.

The Farman aeroplane, "all on," weighed 1,500 lbs. and was estimated (based on kite experiments) to require a thrust of approximately 100 kilos. (=220 pounds) in full flight. This gives $88\times220=19{,}260$ ft. lbs./sec. $=35.2$ thrust h.p. The expected efficiency from Col. (7) of the table is 65 per cent., giving $35.2/0.65=54$ b.h.p., which is consistent with the initial data given above.

The Variable Pitch Propeller

Is perforce a compromise; but since there is some particular setting that corresponds to the normal condition of flight and representing a definite P/D ratio and therefore a definite pitch, that is the setting which must be made the basis of design. Generally speaking, the variable pitch propeller should be one with three blades only, for when set to a light pitch a fourth blade would result in interference and the efficiency would be lowered.

The present article deals only with the proportioning of the propeller. The designing of the blades was dealt with by the writer both in his "Aerodynamics"

and in his 1915 paper to the I.A.E., the basis being that the blade proper is in effect an aerofoil designed to follow a helical path and to take account of the difference in velocity at different points along the blade.

The aerofoil on which the form of the propeller blade is based may be set out in the manner now well known from theoretical considerations, or it may be based on an actual model developed empirically in the wind channel, as in the earlier reports of the Advisory Committee, and indeed in the most recent reports of the Research Committee. For thick sections when there is form resistance over and above that which can be attributed to normal skin-friction, the wind channel determination is the only reliable basis. And sometimes, especially in marine types, the section has to be thick in order to give sufficient strength.

There is one point of importance which suggests that a physical difference exists in the conditions between an aerofoil as tested in the wind channel and the blade of a propeller. In the wind channel " dead water " may accumulate on the upper surface of the aerofoil under test; when this takes place to any great extent the condition of " burble " arises. But in the case of a propeller blade any dead water is shed by centrifugal force as fast as formed and cannot accumulate. Attention was called to this by the writer in 1907 (" Aerodynamics," §215, p. 317). There it was suggested that the form resistance would be augmented; but later the writer expressed doubts as to this, and his present view is that the shedding of the dead water is beneficial, as tending to suppress " burble."

The writer believes that the present article embodies the first material advance made on the theory as presented 25 years ago in his paper cited. Some contributors to the discussion deplored that the theory had not been framed to include some experimental groundwork, but the writer thinks differently; he believes that a theory in such a case as this where there are so many variables is best worked out as *pure theory*, and then submitted to the acid test of experience. If by empirical methods and wind channel experiment a result is reached concordant with theory, then the theory may be regarded as established and to point the way to further advance and to more general treatment. It will be recognised from a study of the I.A.E. paper that the method has but little mathematical foundation and this to some is a source of annoyance and gives rise to suspicion, in any case the solution can only be approximate. But too often a mathematical solution is an exact solution to the wrong problem instead of an approximate solution to the right one; the latter is certainly to be preferred. The position has been wittily expressed by saying the mathematician *cooks his problem to suit his mathematics, whereas the engineer cooks his mathematics to suit his problem*!

SOLUTION OF THE SIMULTANEOUS EQUATIONS RESULTING FROM SUCCESSIVE APPLICATIONS OF THE THEOREM OF THREE MOMENTS TO CONTINUOUS BEAMS.

By F. J. Turton, B.Sc., A.R.C.Sc.

If A, B, C, . . . be the successive bending moments involved, the equations to find them have the following characteristics: The first involves A and B only, the second A, B and C only, the third (if more than three) B, C and D only, and so on for all intermediate equations; finally, the last equation contains only the last two unknowns.

The method to be considered applies more generally, however, when each equation in succession contains only one additional unknown, so that the third may contain A, B, C and D, the fourth A, B, C, D and E, and so on.

To illustrate the theory of the method it will be sufficient to consider three equations:—

$$aA+bB+c=0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$dA+eB+fC+g=0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$
$$hB+kC+l=0 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Let A, B, C be true values, A', B', C' trial values, and let $A=A'+\delta A$, $B=B'+\delta B$, $C=C'+\delta C$.

Put *any* trial value A' in (1) to get B', A' and B' in (2) to get C', then B' and C' in the left-hand side of (3); the result will not be zero unless A' happens to be the true value A.

The operations are as follows:—

(1) $aA'+bB'+c=0$ or $a(A-\delta A)+b(B-\delta B)+c=0$, but $aA+bB+c=0$ so that $a \cdot \delta A+b \cdot \delta B=0$ giving δB in terms of δA . . . . (4)

(2) $dA'+eB'+fC'+g=0$ or $d(A-\delta A)+e(B-\delta B)+f(C-\delta C)+g=0$, but $dA+eB+fC+g=0$ so that $d \cdot \delta A+e \cdot \delta B+f \cdot \delta C=0$ giving, with (4), δC in terms of δA . . . . . (5)

(3) The left-hand side of (3) gives $hB'+kC'+l=h(B-\delta B)+k(C-\delta C)+l$ $=-h \cdot \delta B-k \cdot \delta C$ since $hB+kC+l=0$.

Using (4) and (5), this is put in terms of δA; equating to the arithmetical value from the trial process, δA is determined, A' corrected to the true value A, then B and C found in succession by substitution in (1) and (2).

Equation (3) provides a check. If no approximations have been made, it should be satisfied exactly; if approximations have been made, the left-hand side may not be exactly zero; it should, however, lead to a second value of δA *negligible* in comparison with the value of δA above.

Of the two examples worked out in detail, the first is intended to show that a number of bays give little more than proportionate labour and that a predetermined accuracy in the mathematical values is, in fact, obtained; the second example is more likely to be typical of calculations in practice.

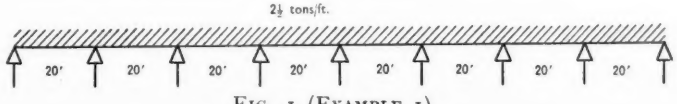

Fig. 1 (Example 1).

EXAMPLE 1.—Simply-supported beam, uniform load $2\frac{1}{2}$ tons/ft., 8 bays each 20 ft. long (Fig. 1).

For any three consecutive supports

$$20\,M_1+80\,M_2+20\,M_3=2\times 2\tfrac{1}{2}\times 20^3/4=10{,}000$$
$$\text{or } M_1+4\,M_2+M_3=500.$$

If the moments at the nine supports are respectively o, A, B, C, D, E, F, G, o, then

$$4A+B-500=0 \text{ giving } \delta B=-4\,\delta A$$
$$A+4B+C-500=0 \qquad \delta C=(16-1)\,\delta A=15\,\delta A$$
$$B+4C+D-500=0 \qquad \delta D=(-60+4)\,\delta A=-56\,\delta A$$
$$C+4D+E-500=0 \qquad \delta E=(224-15)\,\delta A=209\,\delta A$$
$$D+4E+F-500=0 \qquad \delta F=(-836+56)\,\delta A=-780\,\delta A$$
$$E+4F+G-500=0 \qquad \delta G=(3{,}120-209)\,\delta A=2{,}911\,\delta A$$
$$F+4G-500=0 \qquad -\delta F-4\,\delta G=(-11{,}644+780)\,\delta A=-10{,}864\,\delta A$$

Trial value,

$$A'=500/5=100 \text{ say.}$$
$$B'=500-400=100$$
$$C'=0$$
$$D'=500-100=400$$
$$E'=500-1{,}600=-1{,}100$$
$$F'=500-400+4{,}400=4{,}500$$
$$G'=500+1{,}100-18{,}000=-16{,}400$$
$$F'+4\,G'-500=4.500-65{,}600-500=-61{,}600.$$

Hence $\delta A=-61{,}600/-10{,}864=1{,}100/194=5.670103$.

If $\delta A=1{,}100/194$ be used to correct A', subsequent values of B, C, etc., will be exact. In practice, work with fractions will be inconvenient and δA will be rounded off; the greatest error due to this rounding will evidently be in G and by the above, will be 2,911 times the omitted fraction. Thus, if δA be taken as 5.67 the error in any moment will not exceed $2{,}911\times 0.000103\ldots$ and will certainly be less than 0.5.

Taking $\delta A=5.67$	$A=105.67$	Say $A=105.7$ tons/ft.
$B=500-422.68$	$=77.32$	$B=77.3$,,
$C=500-105.67-309.28$	$=85.05$	$C=85.0$,,
$D=500-77.32-340.20$	$=82.48$	$D=82.5$,,
$E=500-85.05-329.92$	$=85.03$	$E=85.0$,,
$F=500-82.48-340.12$	$=77.40$	$F=77.4$,,
$G=500-85.03-309.60$	$=105.37$	$G=105.4$,,

By symmetry, G should equal A, but as expected, differs from it by about 0.3 tons/ft.

$$F+4\,G-500 \text{ is now } =77.40+421.48-500=-1.12.$$

Hence the error in $\delta A=1.12/10{,}864=0.0001\ldots$ as it should be. Thus, even in the absence of symmetry, we can still check the values by the last equation.

EXAMPLE 2.—Simply-supported beam, uniform load 4 tons/ft., 5 bays, 17, 15, 13, 11 and 19 ft. respectively (Fig. 2).

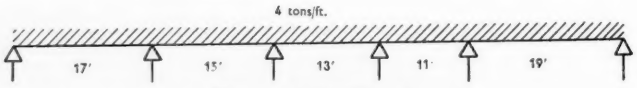

FIG. 2 (EXAMPLE 2).

If the successive bending moments are o, A, B, C, D, o, we have

$$64A+15B-(17^3+15^3)=0 \qquad i.e.,\ 64A+15B-7{,}568=0$$
$$15A+56B+13C-(15^3+13^3)=0 \qquad 15A+56B+13C-5{,}572=0$$
$$13B+48C+11D-(13^3+11^3)=0 \qquad 13B+48C+11D-3{,}528=0$$
$$11C+60D-(11^3+19^3)=0 \qquad 11C+60D-8{,}190=0$$

$15\,\delta B=-64\,\delta A$ $\quad\therefore\ \delta B=-4.266667\,\delta A$

$13\,\delta C=(-15+238.93335)\,\delta A=223.93335\,\delta A$ $\quad\therefore\ \delta C=17.22564\,\delta A$

$11\,\delta D=(55.466671-826.83072)\,\delta A=-771.36405\,\delta A$ $\quad\therefore\ \delta D=-70.12400\,\delta A$

$-11\,\delta C-60\,\delta D=(-189.48204+4{,}207.4400)\,\delta A=4{,}017.958\,\delta A.$

Try $A'\fallingdotseq 7{,}568/79$, say $A'=100$.

$15\,B'=7{,}568-6{,}400=1{,}168$ $\quad\therefore\ B'=77.86667$

$13\,C'=5{,}572-1{,}500-4{,}360.5335=-288.5335$ $\quad\therefore\ C'=-22.19488$

$11\,D'=3{,}528-1{,}012.2667+1{,}065.3542=3{,}581.0875$ $\quad\therefore\ D'=325.5534$

$11\,C'+60\,D'-8{,}190=-244.144+19{,}533.204-8{,}190=11{,}099.060$

$\therefore\ \delta A=11{,}099.06/4{,}017.958=2.76236.$

If δA is taken as 2.762, all the moments will be correct within (70.12 . . .) (0.00036 . . .), *i.e.*, within 0.03; if taken as 2.76, all will be correct within (70.12 . . .) (0.00236 . . .), *i.e.*, within 0.2.

Taking $\delta A=2.76$, $A=A'+\delta A$, $\therefore\ A=102.76$ tons/ft.

$15\,B=7{,}568-6{,}576.64=991.36$ $\quad\therefore\ B=$ 66.09 tons/ft.

$13\,C=5{,}572-1{,}541.4-3{,}701.04=329.56$ $\quad\therefore\ C=$ 25.35 ,,

$11\,D=3{,}528-859.17-1{,}216.80=1{,}452.03$ $\quad\therefore\ D=$ 132.00 ,,

$11\,C+60\,D-8{,}190=278.85+7{,}920-8{,}190=8.85.$

Error in $\delta A=8.85/4{,}017.958=0.002$ . . . as expected.

BUCKLING OF A STRUT UNDER A COMPRESSION WHICH VARIES DISCONTINUOUSLY.

By JEAN DRYMAEL,

Assistant Professor in the University of Brussels.

SUMMARY.

It often happens that in a plane truss all joints are not transversely stiffened. If one joint of the compressed girder of a beam is free, the girder is liable to fail by buckling perpendicular to the plane of the truss, between the adjacent joints. The chart given here enables a rapid determination of the critical loading to be made. The compression and moment of inertia are assumed constant along the length of each bay, but may be different in the two bays.

1. EQUATION.

Let the lengths a_1, a_2 and l be defined by Fig. 1. The compressions are P_1 and P_2 and the moments of inertia I_1 and I_2.

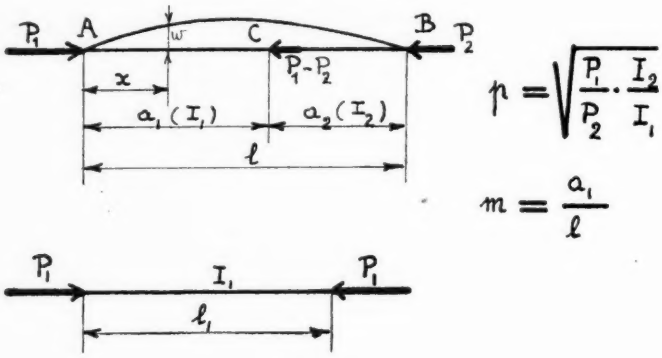

FIG. 1.

It is assumed that P_1 and P_2 remain proportional to each other, their presence being due to a set of external loads liable to increase proportionally. Buckling occurs when there is a state of non-linear equilibrium. On the left hand side of C, the equilibrium of the beam, after buckling, is expressed by the equation

$$M'' + \frac{P_1}{EI_1} M = 0 \qquad . \quad . \quad . \quad . \quad . \quad (1)$$

and on the right hand side by

$$M'' + \frac{P_2}{EI_2} M = 0 \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

Let a fictitious strut be considered of moment of inertia I_1, under the compression P_1; if its length l_1 is properly chosen this strut will fail for the same

value of P_1 as the real one. It is well known that

$$l_1^2 = \frac{\pi^2 E I_1}{P_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

when P_1 reaches its critical value.

In the same way a strut of moment of inertia I_2 will fail under the same critical compression P_2 as the real one if its length equals

$$l_2^2 = \frac{\pi^2 E I_2}{P_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The ratio p of the lengths l_2 and l_1 is known :—

$$p = \frac{l_2}{l_1} = \sqrt{\frac{P_1}{P_2}\,\frac{I_2}{I_1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Without any loss of generality it may be assumed that p is always greater than unity. On the other hand, the ratio of a_1 to l will be called m :—

$$m = \frac{a_1}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The general integral of equation (1) is :

$$M = A \sin\left(\frac{\pi x}{l_1}\right) + B \cos\left(\frac{\pi x}{l_1}\right)$$

and holds from A to C ; the general integral of equation (2) is :

$$M = C \sin\left\{\frac{\pi\,(x-l)}{l_2}\right\} + D \cos\left\{\frac{\pi\,(x-l)}{l_2}\right\}$$

and holds from C to B.

The constants are determined by the boundary conditions. In A and B, the bending moment is zero, whence $B = D = 0$. In C the bending moment and its derivative are the same on both sides, *i.e.*,

$$M_c = A \sin\left(\frac{\pi a_1}{l_1}\right) = C \sin\left\{\frac{\pi\,(a_1 - l)}{l_2}\right\} \quad . \quad . \quad . \quad (7)$$

$$M_c' = \frac{A\pi}{l_1} \cos\left(\frac{\pi a_1}{l_1}\right) = \frac{C\pi}{l_2} \cos\left\{\frac{\pi\,(a_1 - l)}{l_2}\right\} \quad . \quad . \quad . \quad (8)$$

Dividing the members of equation (8) by those of equation (7) :—

$$\frac{1}{l_1} \cot\frac{\pi a_1}{l_1} = \frac{1}{l_2} \cot\frac{\pi\,(a_1 - l)}{l_2} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The problem is solved as soon as the values l_1 and l_2 are found which verify this transcendental equation.

2. Solution.

Introducing (5) and (6) in (9) and multiplying both members by $(1-m)$, one has

$$(1-m) \cot\frac{m\pi l}{l_1} = -\frac{(1-m)}{p} \cot\left[\frac{(1-m)}{p}\,\frac{\pi l}{l_1}\right] \quad . \quad . \quad . \quad (10)$$

To solve that equation it is noticed that

$$(1-m) \cot\left(\frac{m\pi l}{l_1}\right) = X\left(m, \frac{l}{l_1}\right)$$

$$-\frac{(1-m)}{p} \cot\left[\frac{(1-m)}{p}\,\frac{\pi l}{l_1}\right] = Y\left[\frac{(1-m)}{p}, \frac{l}{l_1}\right]$$

The function X has been plotted against l/l_1 for several values of m, from 0 (at infinity) to 1 (Fig. 2). The function Y has been plotted in the same way for several values of $1 - m/p$, between the same limits. Only one of those latter curves has been reproduced (value 0.5) to show the procedure. To each intersection of an X curve with a Y curve corresponds a set of values for m and

$(1-m)/p$ or, which is the same, for m and p. It is easy to interpolate and to draw the curves corresponding to equal values of p. These are shown for values of p between 1 and ∞.

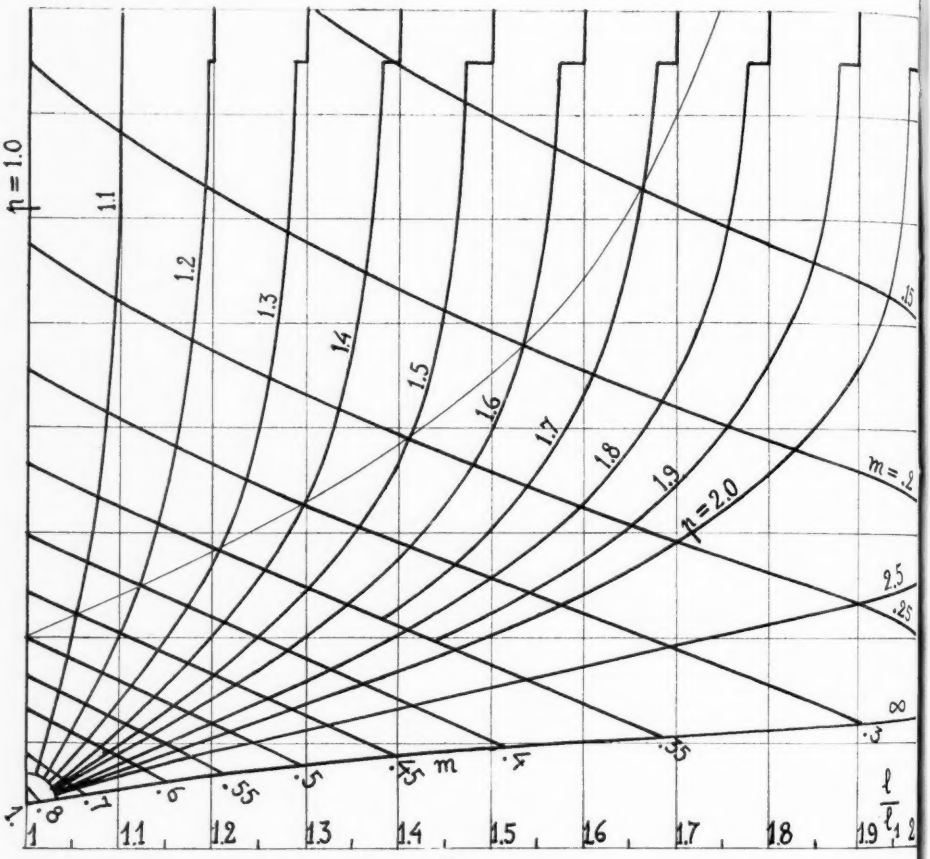

FIG. 2.

3. USE OF THE CHART.

The values of p and m are calculated according to equations (5) and (6). The corresponding point is found on the chart by interpolating between the existing curves. Its abscissa gives the ratio l/l_1 and, consequently, the length l_1 of the first fictitious strut. The critical value of P_1 is given by equation 3. The ratio between P_2 and P_1 being known, the state of loading which corresponds to buckling is fully determined.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

MONTHLY NOTICES

SEPTEMBER, 1941.

Discussions.

The Council have decided that, in spite of the difficulties of war conditions, an endeavour should be made to maintain active interest in technical aeronautics among the entire membership of the Society. It is intended to hold discussions on some or all of the following subjects in the near future. Members of the Society are invited to inform the Secretary which discussion or discussions they would like to attend. It is proposed to hold the discussions on Sundays at the most suitable place in London or the country, depending upon the replies received. Discussions will only be held on those subjects, which, from the replies received, are shown to be of interest to a number of members.

These discussions will be open to all grades of the Society and, to satisfy the needs of security and safety, it will be necessary for those who wish to attend any particular meeting, to notify the Secretary as quickly as possible, so that arrangements can be made for the exact date and place of the meeting.

It must clearly be understood that no one will be allowed to attend the meeting who has not notified the Secretary in advance, and no notice will be given in the Journal of the time or place of the meeting.

When a discussion has been arranged, members who have indicated their interest in that particular discussion will be notified.

The following is a list of proposed subjects. Each subject is followed by the names of speakers who have undertaken to help in the discussion:—

(*a*) Drawing Office Methods.	Mr. S. Camm, F.R.Ae.S. Mr. M. Langley, F.R.Ae.S.
(*b*) Application and Correlation of Wind Tunnel and Full-Scale Testing.	Mr. D. L. Ellis, A.F.R.Ae.S. Mr. R. H. Francis.
(*c*) Vibration Problems.	Dr. A. G. Pugsley, A.F.R.Ae.S. Dr. Ker Wilson.
(*d*) Tolerances, Limits and Inspection.	Mr. L. G. Fairhurst.
(*e*) Drag Reduction.	Mr. W. G. A. Perring, A.F.R.Ae.S. Mr. R. L. Lickley, A.F.R.Ae.S.
(*f*) Control Surface Design.	Mr. R. T. Youngman, F.R.Ae.S. Mr. H. B. Irving, F.R.Ae.S.
(*g*) The Future of Civil Aviation.	Dr. H. Roxbee Cox, F.R.Ae.S. Mr. W. L. Runciman.

The Council will appreciate suggestions for further subjects from members of the Society.

Graduates' and Students' Section.

The lecture by Mr. H. E. Bolton on "Inspection and Construction of Wooden Aircraft," arranged for September 3rd, has been postponed, and also the visit to the British Plywood Company which was arranged for September 13th.

Society's Emergency Address.

It should be made clear that although the Society has published from time to time in the Journal its emergency address and telephone number (which can be used at any time alternatively with those of the Society), the Society functions, and has functioned from the beginning of the war, from No. 4, Hamilton Place, W.1. It will continue to function from London as far as possible, even though some of the staff may have to be moved, others will continue in London itself. It is obvious that events may make things difficult and cause a certain amount of delay, and members are asked to bear these events in mind.

The emergency address is—

Brook House,
Old School Lane,
Brockham, Surrey.

Telephone: Betchworth 189.

Office Opening.

The Offices and Library are open daily from 9.30-5.0 p.m. on Mondays-Fridays. In the winter months the office will shut one hour before black-out time.

Library Catalogue.

With this issue of the Journal is completed the printing of the Catalogue of the Library, a printing which has extended over nine months of the Journal. The Catalogue has been separately paged from the Journal and should be bound separately. Owing to the shortage of paper it will not be possible to have bound copies available from this office.

Associate Fellowship Examinations.

Candidates for the December 1941 examinations are reminded that entries must be received by the Secretary not later than September 30th, 1941.

Election of Members.

The following members were recently elected:—

Fellows.—Wallace William Greenfield (from Associate Fellow), Sydney Oliver Smith (from Associate Fellow).

Associate Fellows.—Eric John Andrews (from Student), Harold Brown (from Associate), Ronald Clemens, William Charles Clothier, Gerald Alexander Fraser Embleton (from Companion), Donald Fraser, Tibor Haas, Clarence Edward Williamson Jones, Arthur Oliver Mattocks (from Graduate), Michael Brian Pelly, Dennis Bernard Peter, Walter M. Reichsfeld (from Companion), Elliott Gray Reid, Edward William Roberts, Harry Hall Smith (from Graduate), Frank Tyson (from Student).

Associates.—Jabez Arthur George Beadle, Gilbert Leonard Bernard Brice, Harry Delacombe, Francis Joseph Delves, Leonard Malabbott, Evelyn Victor Pyle, Frederick Nicholas Slingsby, Raymond Cavill Turner, Arnold Hubert Voss.

Graduates.—Clifford William Bills, Donald William Copley, William Henry Sheppard, Anthony James Cotter Smith, Michael Vivian Smith, Roger Hugh Spikes.

Students.—Lionel Hubert Boustred, Kenneth Francis Brading, Robin Bruce Duncan Campbell, John Barry Corner, Yashvant Desai, Roger

Quentin Eden Eden, Maurice Fuzzard, Eric James Gilbert, Gordon Lander Gunstone, Donald Arthur Hancock, Norman Harold Harvey, Brian Joseph Howison, Frank Richard Longston, Stanley Makepeace Lott, Robert Bulkeley Marsh, Douglas Thomas, Dennis Ian Thompson, Thomas Michael Townshend, Dennis Blackwell Wallis, David Herbert Whaley.

Companions.—Reginald Ernest Cooke, Thomas Mundie Hutchison, Walter Leslie Runciman.

Acknowledgments.

The Council acknowledge with grateful thanks the following gifts from members of the Society:—

Autographed copies of books on the Arctic by Mr. V. Stefansson, presented by Mr. Griffith Brewer.

Thirteen Aircraft Maintenance Books from Lieut. J. H. P. Brymer, Associate Fellow. These maintenance books are very rare and will form a welcome addition to the Society's Library.

The Society's Journal from 1918-1941 from Wing Commander C. A. Pike, Associate Fellow. As quite a number of these Journals are now out of print this gift is a particularly welcome one. Back Journals from Mr. W. P. Savage, Fellow.

Additions to the Library.

Pamphlets in italics, with location reference following in brackets.
Books marked * or ** may not be taken out on loan.

A.a.246.—Airplane Engine Encyclopædia. Glenn D. Angle. Otterbein Press, Dayton. 1921.

A.a.269.—Aeronautics. E. Bidwell Wilson. John Wiley (Chapman & Hall). 1920.

A.a.274.—Mécanique de l'Aviation. Lieut.-Col. Alayrac. Gauthier-Villars, Paris. 1925.

B.a.234.—The Aeroplane of To-morrow. N. Pemberton-Billing. Robert Hale. 1941. 12/6.

*B.a.235-247.—Manuals of Instruction for De Havilland Aircraft. (Operation, Maintenance and Rigging.)

Type D.H.60G. & 60M.	Gipsy Moth	1933.
,, D.H.80	Puss Moth	Undated.
,, D.H.82	Tiger Moth	1934.
,, D.H.83	Fox Moth	1933.
,, D.H.84	Dragon	1933.
,, D.H.85	Leonard Moth	1934.
,, D.H.86A.	Express Air Liner	1935.
,, D.H.87A.	Hornet Moth	1936.
,, D.H.88	Comet	1935.
,, D.H.89	Dragon-Six	1935.
,, D.H.90	Dragonfly	1936.
,, D.H.91	Albatross	1938.
,, D.H.94	Moth Minor	1939.

B.c.55.—*Soaring Flight: its Function in Aviation. E. C. Gordon England. (Lecture before Royal Society of Arts, March 2, 1932, reprinted in R.S.A. Journal, April 15th, 1932.)* (PB.4/8.)

*B.g.101-102.—"*Flight*" Identification Chart of American Aircraft. (R.A.F. and Fleet Air Arm.)* (Wall Card.) Two copies. 6d. 1941.

*B.g.103.—"*Flight*" *Transparent Pocket Identification Chart of British Aircraft.* "*Flight*" *Publishing Co.* 1941. 1/6. (PB.5/16.)

*B.g.104-105.—*Guide to Aircraft Recognition. Leonard Taylor and James H. Stevens. Air League of the British Empire.* 1941. 4*d.* (PB.5/17 and 18.) Two copies.

BB.c.80.—De Havilland Controllable Pitch Airscrew: Service Manual. (Undated.)

BB.c.81.—De Havilland Controllable Pitch Airscrew, Constant Speed Control Unit: Service Manual. (Undated.)

*EE.a.72-79.—De Havilland Aero Engines, Care and Maintenance Booklets.

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J. Laurence Pritchard, *Secretary and Editor.*

OCEAN AIR TRANSPORT

By J. T. TRIPPE, President, Pan American Airways System.

TWENTY-NINTH WILBUR WRIGHT MEMORIAL LECTURE.

Delivered before the Royal Aeronautical Society in the Hall of the Institution of Electrical Engineers, Victoria Embankment, London, on June 17th, 1941.

Lieut.-Colonel the Right Honourable J. T. C. MOORE-BRABAZON, Minister of Aircraft Production (Vice-President): He felt he was there under false pretences, but he was there under orders from the President. From America, he had been given instructions, as Vice-President of the Royal Aeronautical Society, to preside at this meeting. In the meantime the President had returned to England. Of course he was still under his orders, and he had been told to continue to preside over this very important gathering. It was rather odd, because, due to a turn of the wheel, he found himself in the position not only of Vice-President of the Royal Aeronautical Society, but also Minister of Aircraft Production, and this was the first time that an important gathering of the Royal Aeronautical Society had been presided over by a Minister of the Crown. He felt very much the same as when he was President of this Society, and he could assure them that the relationship between one of the Vice-Presidents and the Minister of Aircraft Production was very cordial.

At last there was a very keen recognition of the Royal Aeronautical Society in Government circles, and there was something to be said for this arrangement that he should preside; but if there is anybody more suitable than Mr. Griffith Brewer to preside over any meeting that bore the name of Wilbur Wright, he would like to know who it is, because Griffith Brewer represents in this country the inner soul of the Wrights. Of course there are people here who knew the Wrights, but nobody got " under their skins " so much as Griffith Brewer. On his last trip to America he had been staying with Orville Wright. They would remember how Wilbur Wright astonished a Frenchman who expected a long speech from him, when he merely remarked that he had spent a long time studying the flight of birds and had discovered that there was only one bird which could speak—the parrot—and that was a notoriously bad flyer.

He wondered what Wilbur Wright would have thought of the present position. The conquest of the air . . . what a dream it all was, and what a nightmare it had turned out! He thought it was only fit and proper that from America, where flight was born, should come such help in the air as would redress the evil use that was at present being made of flight. America was giving them the tools—and good tools—in increasing quantities. It might be asked whether the Wrights had brought into the world a blessing or a curse. He thought the answer was that, whatever came, they must see to it that their action, first of all in winning the war, and afterwards by wise use of communications, ensured that there shall be only one answer to that question. There had always been the dream that flight would help the world. Yet he found himself in the strange position of being charged with making the most lethal weapons in the armoury of man!

They were entitled to a little mental relaxation, to pull back the curtain and peep into the future, and see what aviation was likely to be in that future; and if they were entitled to do that, they might put this question: Who would they like to have to talk to about this matter? The answer would come back: They

would want to talk to someone who is the presiding genius of a great air service known throughout the world.

The name of Pan American Airways and that of Mr. Trippe would always be linked together. He is only about 40 years old, yet steeped in all the wisdom of pioneering struggles. The son of a Manhattan banker, of a family which came from Maryland in 1684, educated at Yale, he was a naval pilot during the last war. He had come to talk to them with unrivalled knowledge, and thereby to show them a keenness and sympathy for which they thanked him and which they deeply appreciated. To-night was the 29th Wilbur Wright Memorial Lecture; the title was "Ocean Air Transport." He presented to them Mr. Juan T. Trippe.

OCEAN AIR TRANSPORT.

By J. T. TRIPPE, President, Pan American Airways System.

That this distinguished gathering has convened here to-day, amid the chaos of a war-torn world, for a lecture on civil aeronautics is indeed a singular expression of the true spirit of our profession. It is, I think, graphic proof of the fact that all of us in aviation are looking forward to the day when the aeroplane can lay aside its duties of destruction and once more assume its truly great rôle as a constructive force in world civilisation.

I am, therefore, particularly sensible of the privilege of delivering, at this historic meeting, the Twenty-ninth Wilbur Wright Memorial Lecture. Under any circumstances, we in America feel that an invitation to address you, the parent body of the aeronautical profession, is one of the highest honours which can be attained by an individual engaged in aviation.

My rôle here, of course, is hardly that of an individual. In the narrowest justifiable sense, I can but speak for what has been accomplished by the 7,000 men and women who are the Pan American Airways System. That company, in itself, is singularly the product of a community effort of a large part of American industry. My purpose to-night, however, is to speak from an even broader viewpoint than that of a representative of any organisation or group of organisations.

It has been scarcely two years since civil aviation established the first scheduled air transport service across the North Atlantic—a goal toward which the airlines of many nations had been working for almost two decades. Were it not for the war, three nations, and perhaps six, would now be participating actively in the development of ocean flying along this major world trade route. Perhaps five nations would also have established operations on the South Atlantic.

Yet the war has left only the United States in a position to carry on with scheduled trans-oceanic air transportation. Upon us, therefore, has rested the task of maintaining essential overseas air communications, as well as the responsibility for continuing the development of this vitally important phase of the air transport art.

I have conceived my talk to-night as a report upon the manner in which we have attempted to discharge that responsibility, together with a brief analysis of some of the technical development of the Pan American Airways System to date—a development which has made possible the trained personnel, flight equipment, and operating procedure required for over-ocean air transport service.

START OF OVERSEAS AIR TRANSPORT.

International air transportation throughout Europe began to develop swiftly before the end of 1919. It was not until some years later, actually in October, 1927, that the first American international air service was inaugurated, when Pan American Airways undertook to establish scheduled operations between Key West and Havana.

This, our pioneer effort, involved a 90-mile route across the Straits of Florida. From the very outset, the policy adopted by Pan American Airways required the use of multi-unit power plants. This we considered an essential requisite for over-water flying. Only aircraft so equipped could possibly provide the necessary reserve power which, even with the loss of one engine, should assure sustained flight through to destination, or safe return to the port of departure.

FIG. 1.

First American "Over-seas" Transport (1927).

A Fokker F-7. Equipped with special flotation apparatus, this aircraft was used for the first service of the Pan American Airways System between Key West, Florida, and Havana, Cuba.

FIG. 2.

The American-built Fokker F-10 Trimotor (1928).

This advanced version of the F-7 was used by the Pan American Airways System to extend the American air routes in the West Indies as far as San Juan, Puerto Rico.

In 1927 no marine-type aircraft had yet been developed in America suitable for air transport operation. The Fokker F-7 tri-motored landplane (Fig. 1) with its demonstrated ability to maintain flight on only two of its three engines, however, was soon to be available on the American market.

Equipped with three Wright Whirlwind engines of 220 horse-power each, these planes could lift a gross weight of 9,700 pounds, and had a cruising speed of ninety miles per hour. The wings of wooden construction lent themselves to the

installation of flotation gear which contributed an additional safety factor. Even equipped with supplementary marine accessories, they permitted us to carry mail and eight passengers. These aircraft and the larger and improved Fokker F-10 tri-motored transports (Fig. 2), available the next year, enabled us to extend service across the intervening over-water sectors of the West Indies as far south as Puerto Rico.

FIG. 3.

The First American-developed Marine Air Transport (1928).

The Sikorsky S-38 Amphibian. Developed for the extension of the Pan American routes beyond Puerto Rico to South America and from Miami via Yucatan and Central America to Panama.

FIG. 4.

The "Commodore" Flying Boat.

Built by the Consolidated Aircraft Corp. (1929), *used on trans-Caribbean and East Coast South America services of the Pan-American Airways System.*

Between Puerto Rico and Trinidad, however, there were available no adequate sites for airports or intermediate fields which would permit the extension of this eastern route through the lower Antilles. Likewise, our projected western route, which branched from Cuba across the Straits of Yucatan, and thence through Central America to the Panama Canal Zone, required an entirely different type of aircraft.

For these essential extensions of our service the Sikorsky S-38 amphibian (Fig. 3) was utilised. This pioneer American marine transport, capable of operating to and from both land airports and water areas, was equipped with two 420 horse-power Pratt and Whitney " Wasp " engines. Because of its inherent seaworthiness, it enabled us to carry seven passengers, and mail, within its gross weight limit of 10,480 pounds, and to establish two trunk line routes, by following the perimeter of the Caribbean, between North and South America.

Availability of more powerful engines, and further departures in hull and wing design were incorporated in the first twin-engined American flying boats designed for transport use, the Consolidated " Commodore " (Fig. 4), which made possible a next step in our overseas transport development. This took the form of the first direct service across the 631-mile open-water sector between the Island of Jamaica and the Panama Canal Zone.

In 1931, this represented the most ambitious overseas operation so far undertaken by scheduled air transport. In terms of the performance characteristics of this pioneer flying boat and the many unsolved problems involved in such long range operations, this was indeed a formidable distance. The " Commodores " permitted us to establish service, with restricted traffic loads, along this natural traffic artery between the continents.

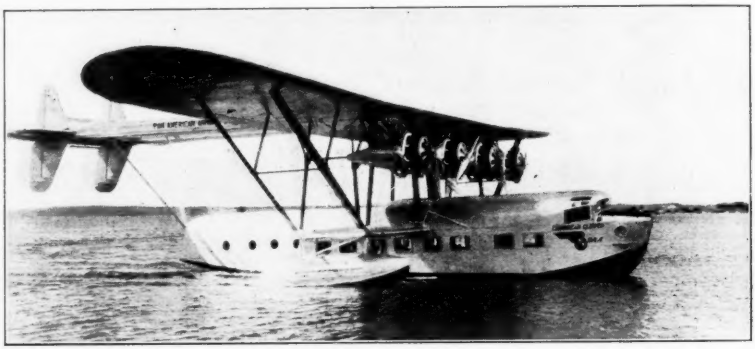


FIG. 5.

The First American Four-engined Transport (1932).

Developed for Pan American Airways Caribbean services by the Sikorsky Airplane Company.

However, to carry commercially practical loads, with adequate safety, over such a long range, would require a four-engined marine aircraft much larger than any transport so far projected in the United States. A step toward this goal was the Sikorsky S-40 (Fig. 5) of which the first of three entered service early in 1932.

THE " ATLANTIC LABORATORY."

The development of these planes, built to specifications based on our growing experience, made an important contribution toward overseas transport. The impressive size of these ships, which could carry 40 passengers on the Miami-Havana run and which had a gross weight of 34,600 pounds, did much to break down the prevailing public resistance to over-water flying. From the standpoint of our industry, they served as a convincing demonstration to designers and manufacturers of the potentialities of increased size and horse-power in aircraft for international—and particularly for over-water—operation.

On the side of operating technique, the S-40s provided us with many new lessons in maintenance and surface handling of large-scale aircraft. Static condi-

tions, typical of the tropical sphere of our operations, had required the use of radio telegraphy rather than voice communication. As a result, the standard Pan American Airways crew had always consisted of at least two pilots and a radio operator. Now, the use of four-engine aircraft led us to add a fourth member to the flight crew, an engine specialist. To ensure accurate navigation across our trans-Caribbean sector, we undertook to adapt celestial navigation to air transport purposes and to increase the range of our radio direction-finders. We also extensively supplemented our weather service organisation to provide improved weather analyses for this overseas flying.

Thus it was that the Caribbean became a working laboratory in which, under large-scale and actual operating conditions, we were able to gain invaluable experience which was to form the basis for future undertakings of trans-oceanic operations.

For the first seven years of its history the Pan American Airways System was engaged in the major and absorbing task of establishing an airline network between the Americas. First, by plane and muleback, by steamer and dugout canoe, went young engineers to blaze the trail, to carve airports out of jungle, to clear sites for weather stations in lonely mountain passes. Their aides were Indians who had no idea of what an automobile might be and who had never heard of a railroad train. Following them went builders to construct hangars and passenger stations, hotels, and the two-hundred-odd weather observatories and radio control stations which to-day guide the aircraft flying the airways between the Americas. By 1934, the initial stage of this pioneering effort was completed with the extension of service to every important country and colony in the three Americas.

Atlantic Research Undertaken.

But even while these airways were extending southward, development work had been well started toward a transatlantic air line. Since little authentic information was then available with respect to climatic and meteorological conditions as they affected transatlantic flying, research expeditions, some entirely our own, others in which we were associated with American and European universities and scientific bodies, were dispatched to Iceland, to Greenland, to Labrador, and Newfoundland. Company engineers conducted similar surveys at the Azores as well as other points in Europe and Africa. Supplementary flight surveys were made in the far North. Special weather stations were put aboard transatlantic liners to aid in the development of a comprehensive weather forecasting and reporting service.

Through these same years our technical staff had been constantly studying the steady progress of aircraft and power plant design in all its elements. As early as 1932, as a result of such studies, we felt justified in issuing tenders to manufacturers for the design and development of four-engine flight equipment which we hoped would permit the establishment of a seasonal transatlantic service.

Development of these aircraft contributed not only to our own progress but also to the air transport industry as a whole. The Sikorsky S-42 (Fig. 6), of which the first was delivered to us in 1934, effectively disproved the prevailing theory that large heavier-than-air craft were not commercially sound; that the larger the plane the less load it could carry in proportion to its own weight. This plane, equipped with four 700 horse-power Pratt and Whitney "Hornets," cruised at 160 miles per hour. With a gross load rating of 38,000 pounds (increased in later models to 42,000 pounds), this plane had a ratio of useful to gross load of 36 per cent., a remarkable achievement for that time.

With the characteristics and performance of this aircraft I am sure you are all familiar. Many of you, I know, had an opportunity to inspect one of these planes at first hand during the transatlantic survey flying of 1937. These air-

craft, of which we were to secure a total of ten, have done yeoman service in many regions. Equipped as a thirty-two passenger transport for ranges up to 1,000 miles, this fleet, until recently, was the nucleus of our express service to South America and along the east coast of that continent to Rio de Janeiro and Buenos Aires. Equipped with extra tanks, it permitted us, as I shall describe later, to conduct survey flights on the routes we projected on the Pacific and the Atlantic.

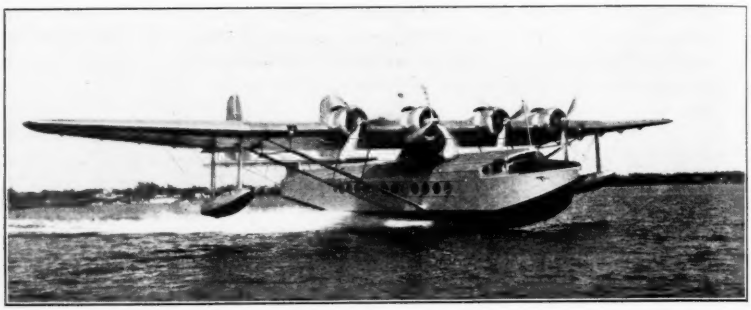


FIG. 6.

The First American Ocean Transport (1934).

A Sikorsky Clipper-type S-42 with which the Pacific and Atlantic routes were surveyed.

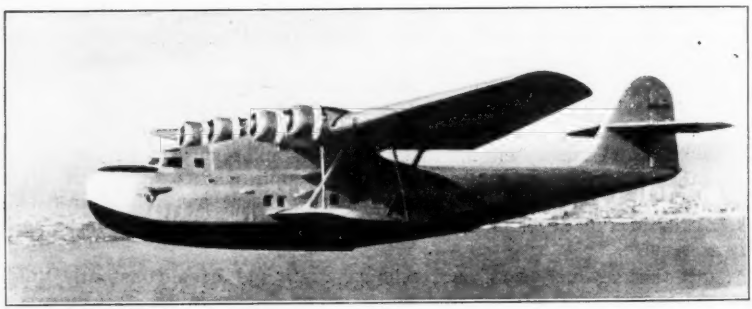


FIG. 7.

The First American Ocean-Passenger Carrier (1935).

The Martin Clipper-type M-130 with which the first trans-oceanic passenger and mail service was instituted—on the route from California across the Pacific Ocean to the Philippines, Hong Kong and China.

The second type of ocean aircraft, the Martin M-130 (Fig. 7), equipped with four Pratt and Whitney " Twin Wasps " of 900 horse-power each, had a gross load rating of 52,000 pounds and an empty weight of only 29,500 pounds. Two of these planes were delivered to us in 1935 and a third in the Spring of 1936. Capable of carrying, with ample fuel reserve, a substantial load of mail and ten passengers on a non-stop flight in excess of 2,000 miles, this Martin Clipper thus gave us the physical means, as early as 1935, of establishing a transatlantic service. For reasons which I will outline later, however, we were not able, at that time, to inaugurate actual flight operations on the North Atlantic.

Transpacific Air Service.

In 1934 had begun an adventure in ocean air transport in an entirely different direction. To the west of us, across a chain of islands which were either territories, possessions, or associated commonwealths of the United States, lay an 8,683-mile route to the coast of Asia. Unable to move forward on the Atlantic, we applied our aircraft, our trained personnel, and the operating technique which we had developed in the Caribbean for the Atlantic service to the establishment of this transpacific airway.

In all respects, save those pertaining to difficult operating conditions of winds and weather, the physical task of building a transpacific airway presented greater problems than did the corresponding project on the Atlantic. My use of the term "adventure" for this Pacific undertaking was an advised one. Honolulu, Midway, Wake, Guam, Manila—even the names of the ports-of-call of this projected air line, lent story book glamour to the enterprise. All the proposed bases offered harbours or lagoons satisfactory for seaplane operations. Docking requirements, the radio communication set-up, maintenance facility needs and fuel storage requirements, were problems which could be met, premised on past experience on other Pan American routes.

Everything else varied grotesquely, Honolulu and Manila offered all the facilities, resources and advantages available in any well-developed centre of population. At these points our principal task was to install our radio and specialised base facilities. At Guam, radio and base facilities would have to be supplemented by the construction of some sort of hotel facilities for Clipper passengers. On Midway Island there was a small colony in charge of the cable relay station, but there were no facilities for newcomers. Wake was a tiny low-lying "V-shaped" atoll, a thousand miles from the nearest land. Exposed on all sides to the surf, it had no harbour protection of any kind. There was no vegetation save matted underbrush, no fresh water, no food, no shelter.

We determined to tackle the task of setting up complete bases on all five of these islands, in a single expedition. On March 27, 1935, our colonising steamer, the s.s. "North Haven," nosed heavily off through the Golden Gate bound on that four-months assignment. Never had a ship such a cargo or complement of passengers. Aboard her had been shipped two complete villages, five air bases, a quarter million gallons of fuel, 44 airline technicians, a construction force of 74, food to feed them for months and, literally, 1,018,897 other items of equipment and material.

Even before this steamer reached Midway early in April on its arduous but successful mission, the Pan American Clipper—a specially fitted Sikorsky S-42—took off on a round trip survey flight of the 2,400-mile sector of this route lying between San Francisco and Hawaii. Within the next few months, as each succeeding island base was set up and put into operation, this same Clipper conducted, step by step, flight surveys of the remaining legs of the route. The 1,304 miles between Honolulu and Midway—1,185 miles between Midway and Wake—1,508 miles between Wake and Guam—1,589 miles between Guam and Manila, all were completed "without incident." With the delivery of the first Martin Clippers and the completion of its service test we were able to inaugurate, on this route, the first scheduled transoceanic air service for passengers.

Problems Delaying Atlantic Service.

In the meantime our development work continued on the transatlantic routes. Inquiries were released to manufacturers inviting tenders for more modern and efficient aircraft of higher cruising speed and greater payload. Early in 1936 we contracted with the Boeing Aircraft Company of Seattle for six four-engined flying boats (Fig. 8), to be known as the Boeing type B-314, which were to have a gross load rating of 84,000 pounds, and to be capable of carrying 30 passengers in berths under average conditions across a 2,000-mile non-stop

flight sector (Fig. 9). Once more I assume that I am speaking to you of an aeroplane with which you are quite familiar. New features to be incorporated in these ships were companionways to permit accessibility to engines in flight and a Flight Deck (Fig. 10) ample for an entire flight crew, located above and completely separated from the passenger compartment. With such planes as these we knew that we could substantially improve our service in the Pacific and

FIG. 8.

The Boeing-built Clippers for Atlantic and Pacific Routes (1939).

Three of these, the largest transport aircraft in service, were used to institute and maintain the first transatlantic passenger and air-mail service.

SUCCESSIVE DEVELOPMENT OF MARINE AIR TRANSPORTS

Sponsored by the Pan American Airways System

1929	1931	1934	1935	1939
SIKORSKY S-38	SIKORSKY S-40	SIKORSKY S-42	MARTIN M-130	BOEING B-314
2 Pratt & Whitney "Wasps" 420 HP	4 Pratt & Whitney "Hornets" 575 HP	4 Pratt & Whitney "Wasps" 700 HP	4 Pratt & Whitney "Twin Wasps" 900 HP	4 Wright "Double Row Cyclones" 1550 HP
Gross: 10,480 lbs.	Gross: 34,600 lbs.	Gross: 38,000 lbs.	Gross: 52,000 lbs.	Gross: 84,000 lbs.

FIG. 9.

Successive Development of Marine Air Transports sponsored by the Pan American Airways System.

be even more adequately prepared to set up a pioneer service in the Atlantic which we hoped to be able to inaugurate several years later.

Unfortunately, as you so well know, international air transportation in its brief history has been confronted not alone with grave technical problems but also complicated political problems. With the adoption of the Paris Convention of 1919 covering international commercial aviation, followed by the Havana Convention and other similar enactments, the law of the air departed sharply from maritime traditions. There is no "freedom of the air." Every country now claims full sovereignty over its air space and no aircraft, even of a friendly power in time of peace, can fly to or over the territory or territorial waters of any other country without direct permission or treaty authorisation. Such was the situation on both sides of the Atlantic.

FIG. 10.

The Flight Deck of a Transatlantic Clipper.

Illustrating the working stations for the Pan American Multiple Crew. The photograph shows left to right: Navigation Officer at his chart table; The Captain left, First Officer at right at the flight controls (automatic pilot is shown on the instrument panel between the two pilots); the Flight Radio Officer (the manually-operated direction finder loop extends from the ceiling directly above his station); the Flight Engineer.

Before transport operations could be set up between the United States and Europe, many of these political questions had to be settled. It is sufficient for the purpose of our summary of transoceanic operations to say that it was not until 1937 that sufficient progress in the solution of these political problems had been achieved to permit the start of actual transatlantic survey flights.

FLIGHT SURVEYS—AND THE ROUTES.

From prior studies we knew that so long as we were limited to aircraft which could not operate commercially on non-stop flights between the United States and

European capitals that there were two general routes which offered best possibilities for a successful initial transatlantic service. The first of these, for the purpose of convenience, can be referred to as the Great Circle Route to Great Britain and France via Canada, Newfoundland, and Ireland. The second, the Mid-Atlantic, extended from New York via the Azores and Lisbon. Bermuda offered possibilities as an alternate " stepping stone " on this Mid-Atlantic route. Winter conditions on the American, Canadian and Newfoundland coasts limited flying-boat operations on the Great Circle Route to a seasonable basis.

Between June and September of 1937, a series of five engineering surveys were conducted by Pan American Airways, utilising an S-42 especially equipped for flight research. Beginning on June 25, a preliminary survey covered the projected route from New York 601 miles to Shediac, New Brunswick, where an intermediate station had been established by Pan American. A second continued from New York, via Shediac to Botwood, Newfoundland, 471 miles farther. In July, on the same day that a survey plane of Imperial Airways left Foynes, the Pan American Clipper took off from Botwood on the first transport survey of the critical 1,995-mile sector of this Great Circle Route lying between Newfoundland and Ireland. I feel I need hardly put into words the regret of all of us in Pan American Airways that the course of history has not permitted our friends in the British air transport industry to continue thus to fly at our side in scheduled as well as survey operations. The final survey over the Mid-Atlantic Route was launched on August 16th from New York to Bermuda, thence via the Azores and Lisbon, to Marseilles. From Marseilles the Clipper continued to Southampton before return to the United States again via Marseilles and Lisbon.

These surveys, conducted under strict transport routine, familiarised flight crews with the conditions at bases along the routes and served to confirm the adequacy of our ocean transport flight technique as applied to transatlantic operations. In spite of the comparatively mild season of the year these flights also confirmed our general respect for the difficult weather problems we knew to be characteristic of the Atlantic area. Winds at altitudes at which we planned to operate proved even stronger and more stubborn from the west than we had expected. Final ocean swell observations in the Azores forecast a difficult operations problem at that essential refuelling point.

Start of Translantic Service.

While these surveys were completed in 1937, conditions arose during the following year to postpone further the institution of scheduled service. As some of you may recall, it was not until May 20, 1939, that the Yankee Clipper, first of our new Boeing B-314 ocean transports, headed out from New York for Europe on official flight No. 1, instituting the first scheduled aeroplane mail service over the Atlantic ocean. By June 24th, scheduled service had been inaugurated across both the Great Circle and mid-Atlantic routes. By July, passengers as well as mail were being carried in both directions on regular weekly schedules to Southampton and to Marseilles.

Effects of the War.

This pioneer service, confronted by many problems of its own, was soon to be affected by circumstances of a more serious nature. Three months after the service started, it became obvious that War was imminent in Europe. It would be necessary to withdraw the terminal of the Great Circle Route from Southampton to Foynes, in neutral Ireland, and similarly to withdraw from Marseilles to Lisbon on the mid-Atlantic Route.

Early in October, as had been foreseen, weather conditions along the Great Circle Route required us to consolidate both services along the New York-Lisbon airway with a single intermediate stop at the Azores. If it had not been for the War, we would, of course, have continued directly to serve Southampton via Lisbon. In the Spring, we would have re-established service

across the Great Circle Route if the enactment of America's " Neutrality Act " had not intervened to make the area to the west of Ireland a combat zone and hence one which we could not cross. All flight operations have since been conducted across the mid-Atlantic and southerly routes.

From an operating problem point of view, the Atlantic has, during the past two years lived up to its advance reputation. Even during the first months of operation, prior to the outbreak of War, difficulties already encountered were sufficient to confirm the North Atlantic as being, technically, the most difficult operation of any major aerial trade route.

The outbreak of war, forcing curtailment of regular steamship service, left the transatlantic air route one of the most important arteries between our two countries. Traffic demand which had been encouraging but not spectacular in the early months of service climbed swiftly to volumes ten times greater than the original estimates.

IMPROVEMENTS IN SERVICE.

A few months after the opening of operations in 1939, and shortly after the outbreak of war, we released an order for six additional Boeing B-314-A transports for delivery early in 1941. Four of these have now been delivered, three of which have been transferred to the British Government. The remaining aircraft on this order should enable us soon to increase our frequency of service from three to six round trips each week on the Atlantic.

Meanwhile, we have attempted to take every step which might increase the payload capacities of our ships to carry the greatest possible volume of their important wartime traffic. We have been able to make changes in our engines and propellers, to increase our operating efficiency, and decrease fuel loads. Every spare ounce of furnishings, equipment and even paint has been stripped from the Clippers for the same purpose. Instead of operating all scheduled non-stop between Bermuda and Lisbon, as the improved B-314s are now capable of doing, we schedule flights into and out of Horta, whenever weather and sea conditions permit, in order to make available the approximately 5,000 pounds eastbound and 3,000 pounds westbound additional payload.

The flight logs show how difficult were operations through the winter of 1939-1940. Many flights were delayed due to harbour conditions at Horta. Others were cancelled due to extremely strong westerly winds and unflyable mid-ocean storms covering areas too wide to detour; and still others when flown were able to carry only very limited westbound payloads.

As a result, we surveyed and put into operation during this last winter of 1940-1941 a route for westward crossings which swung far south from the usual route. Heading south from Lisbon, the Clippers landed at Bolama in Portuguese Guinea, West Africa, then turned westward to Belem in Brazil, thence northward to New York via Trinidad, and either Puerto Rico or Bermuda. Such a route, while 4,085 miles longer than the Lisbon-Azores-Bermuda-New York route, and correspondingly more expensive to operate, nevertheless substantially offset the increased cost in the improvements thus effected in terms of an increased percentage of schedules completed and an increased number of passengers, in addition to the mails, moved from Europe to the United States.

By overflying Horta on eastbound trips throughout the winter and following the South Atlantic route on westbound trips, the Clippers were able to complete 50 per cent. more westbound crossings than during the previous winter. Of a total of twenty-five trips scheduled only fourteen were completed in three winter months of 1940. In 1941, twenty-one of these flights were completed via the Southern Route, a record of 84 per cent. performance against 56 per cent. for 1940. Traffic-wise, the change of route proved equally satisfactory. In the winter of 1940 only 286 persons were carried from Lisbon to New York. During the winter of 1941, this total reached 471 for the period and this in spite of an increase of mail loads from 33,247 pounds to 45,404 pounds.

Specialised Aids Developed.

My account of our transatlantic operations must seem so far to be largely a tale of difficulties. Yet, despite these early growing pains, despite the severe difficulties imposed by the war (which among other things restricted the scope of the weather service on which much effort had been spent)—despite all these things we feel that, even in these two difficult years, some progress can be assumed in the developing art of ocean air transport. That our operating organisation has succeeded in maintaining a reasonable record of service, and to date an unblemished record for safety is, to all system personnel, a source of real gratification. The methods developed to achieve this record represent our contributions to air transport. They are, to a large extent, original with Pan American Airways. They have, to my knowledge, never been previously discussed in detail.

First came the development of the Multiple Flight Crew, through whose specialised organisation and training it has been possible to conduct transport flights as long as twenty-four hours in duration. Second, the accessibility of power plants, a feature which Pan American has sponsored, and the practical results of which have made this a pre-requisite for future oceanic operation. And third, the development of a system of scientific flight control, through an individual ocean flight-plan, which directly applies the analysis of any given set of conditions to the end that the flight shall be conducted on a basis of known quantities and toward deliberate elimination of all possible uncertainties.

I. The Multiple Flight Crew.

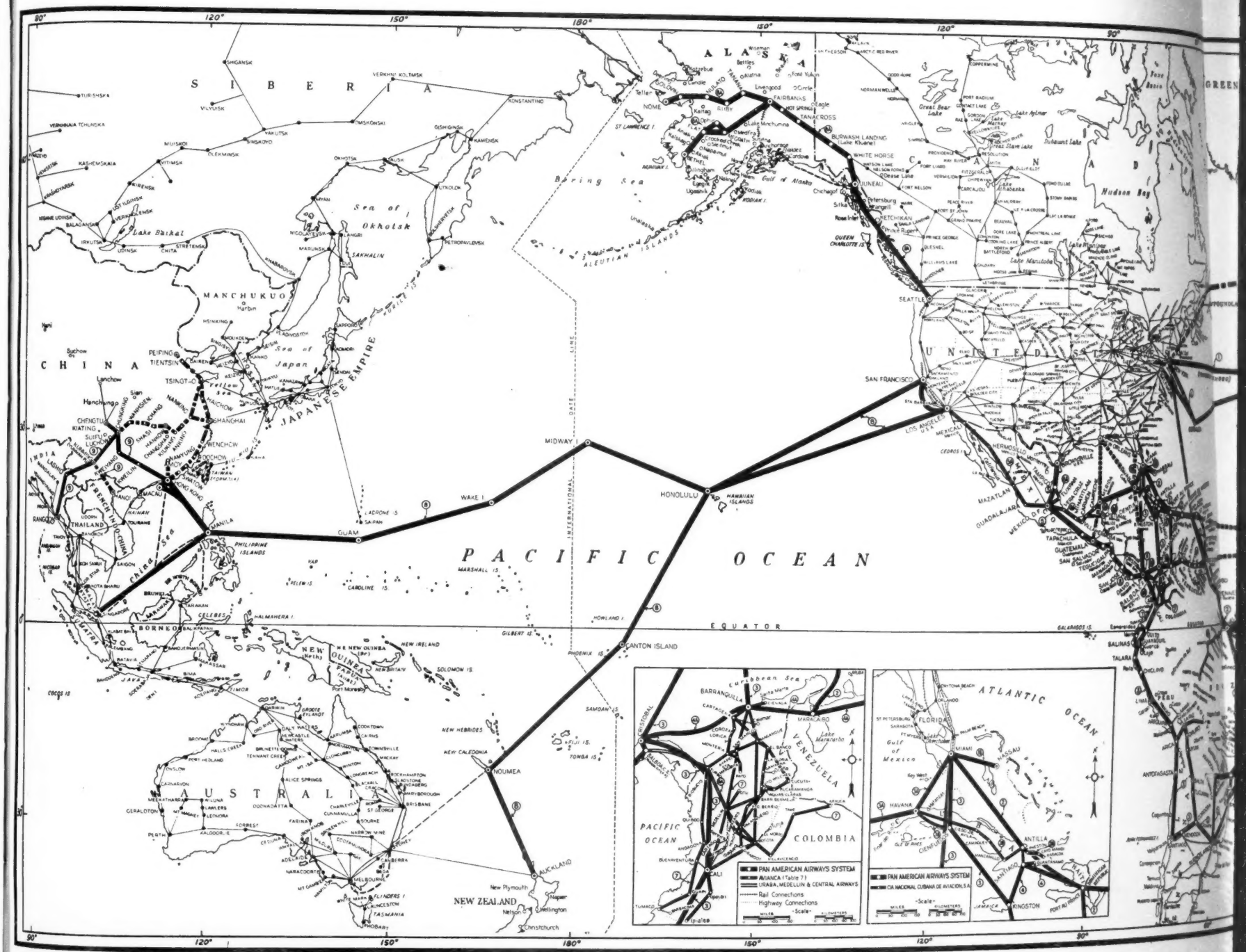
I previously mentioned how, at the inception of our four-engined operation, we had adopted as standard a four-man crew. Adequate for Caribbean operations, our analysis of ocean transport problems had indicated the need for crews far larger and individually trained for specialised assignments.

We considered the primary personnel requisites of ocean air transport to be: (1) Expert direction of the flight; (2) Piloting; (3) Navigation; (4) Control and care of power plants; (5) Maintenance of communications; (6) Passenger service.

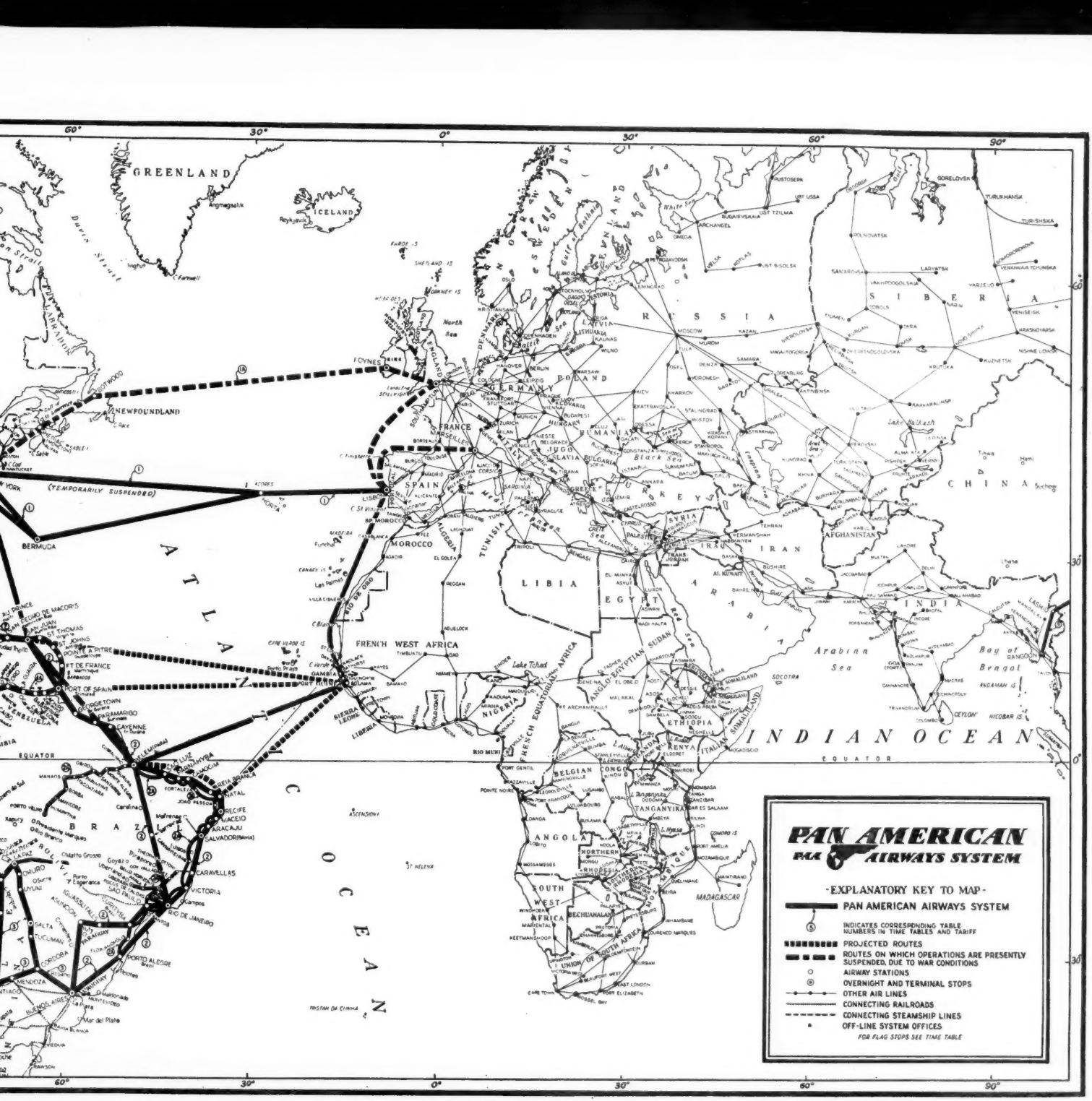
Thus evolved the concept of to-day's standard Multiple Flight Crew, composed of a Captain and his crew of ten. Directly responsible to him are five officers, qualified as specialists in the primary departments—piloting, navigation, engineering, communications, and passenger service. Each of these has a qualified assistant capable of relieving him for rest periods. The training of this composite group ensures its smooth and automatic functioning as a complete flight organisation. The crew of eleven, which typically mans our transatlantic Clippers, is as highly organised as any which ever operated a destroyer or a submarine.

The Clipper Captain is the chief administrative officer. He is invariably a veteran of many years of experience on Pan American's overland, as well as overseas divisions. In addition he has qualified himself, through research and study, to attain the rank of Master of Ocean Flying Boats. This rank testifies that the individual has successfully demonstrated sound judgment throughout his professional career and is an expert in all phases of piloting. He is also qualified in aeronautical engineering, in engine and aeroplane mechanics, in meteorology, in radio operation. He holds the equivalent of a master mariner's ticket. His rank further testifies that he has qualified himself in the subjects of international law, marine law, and business administration as required for the performance of his duties. In trans-ocean operation, all of these special qualifications are at one time or another required of the Captain of an ocean-going flying boat. It has been our experience that five years of training and post-graduate study are required to make a master ocean-flight Captain out of an excellent pilot.

The *Captain* is directly responsible at all times during the flight for the safety and well-being of the aircraft, of the persons and goods carried, for the conduct


PACIFIC OCEAN
SIBERIA
ALASKA
CANADA
CHINA
MANCHUKUO
Harbin
Sea of Okhotsk
Bering Sea
Sea of Japan
Yellow Sea
East China Sea
South China Sea
JAPANESE EMPIRE
UNITED STATES
Hudson Bay
Great Bear Lake
Great Slave Lake
Lake Athabasca
Lake Winnipeg
Lake Manitoba
Lake Baikal
ALEUTIAN ISLANDS
Gulf of Alaska
Gulf of Mexico
Caribbean Sea
ATLANTIC OCEAN
PHILIPPINE ISLANDS
MARSHALL IS.
CAROLINE IS.
GILBERT IS.
PHOENIX IS.
HAWAIIAN ISLANDS
MIDWAY I.
WAKE I.
GUAM
SAIPAN
HOWLAND I.
CANTON ISLAND
EQUATOR
INTERNATIONAL DATE LINE
NEW GUINEA (Neth.)
NEW GUINEA (Br.)
NEW GUINEA (Aust.)
NEW IRELAND
SOLOMON IS.
NEW HEBRIDES
NEW CALEDONIA
FIJI IS.
TONGA IS.
SAMOAN IS.
NOUMEA
AUSTRALIA
NEW ZEALAND
Auckland
Wellington
Christchurch
TASMANIA
COLOMBIA
VENEZUELA
FLORIDA
PAN AMERICAN AIRWAYS SYSTEM
AVIANCA (Table 7)
URABA, MEDELLIN & CENTRAL AIRWAYS
Rail Connections
Highway Connections
CIA NACIONAL CUBANA DE AVIACION, S.A.
-Scale-
MILES
KILOMETERS

150°
120°
90°
60°
ALASKA
Fairbanks
Anchorage
Juneau
Whitehorse
Great Bear Lake
Great Slave Lake
Lake Athabasca
Lake Winnipeg
Lake Manitoba
Hudson Bay
Foxe Basin
Hudson Strait
CANADA
UNITED STATES
Seattle
San Francisco
Los Angeles
New York
Bermuda
Nassau
Honolulu
Hawaiian Islands
Mexico City
Guadalajara
Mazatlan
Hermosillo
Guatemala
San Salvador
Tegucigalpa
Managua
San José
Panama
Caracas
Maracaibo
Barranquilla
Cartagena
Bogotá
Cali
Medellin
Colombia
Venezuela
Lima
Peru
Quito
Guayaquil
Salinas
Talara
Chiclayo
Arequipa
Antofagasta
Arica
Tucuman
Salta
Cordoba
Mendoza
Santiago
Concepcion
Valdivia
Puerto Montt
Temuco
Osorno
Punta Arenas
Ushuaia
Buenos Aires
Rio de Janeiro
Sao Paulo
Belem
Manaus
Recife
Fortaleza
Natal
Salvador
Brasilia
Asuncion
Montevideo
Galapagos Is.
Equator
Pacific Ocean
Atlantic Ocean
Caribbean Sea
Gulf of Mexico
Florida
Miami
Havana
Kingston
Jamaica
Haiti
Antilla
Santiago
Cienfuegos
Nassau
Bahamas
PAN AMERICAN AIRWAYS SYSTEM
AVIANCA (Table 71)
URABA, MEDELLIN & CENTRAL AIRWAYS
Rail Connections
Highway Connections
-Scale-
MILES
KILOMETERS
PAN AMERICAN AIRWAYS SYSTEM
CIA NACIONAL CUBANA DE AVIACION, S.A.
-Scale-
MILES
KILOMETERS


GREENLAND
ICELAND
NEWFOUNDLAND
BERMUDA
(TEMPORARILY SUSPENDED)
AZORES
RUSSIA
SIBERIA
CHINA
GERMANY
POLAND
FRANCE
SPAIN
MOROCCO
ALGERIA
TUNISIA
LIBIA
EGYPT
TURKEY
IRAN
AFGHANISTAN
INDIA
FRENCH WEST AFRICA
BRAZIL
ATLANTIC OCEAN
INDIAN OCEAN
Arabian Sea
Bay of Bengal
Black Sea
Lake Tchad
EQUATOR
MADAGASCAR
PAN AMERICAN
PAA AIRWAYS SYSTEM
-EXPLANATORY KEY TO MAP-
PAN AMERICAN AIRWAYS SYSTEM
INDICATES CORRESPONDING TABLE NUMBERS IN TIME TABLES AND TARIFF
PROJECTED ROUTES
ROUTES ON WHICH OPERATIONS ARE PRESENTLY SUSPENDED, DUE TO WAR CONDITIONS
AIRWAY STATIONS
OVERNIGHT AND TERMINAL STOPS
OTHER AIR LINES
CONNECTING RAILROADS
CONNECTING STEAMSHIP LINES
OFF-LINE SYSTEM OFFICES
FOR FLAG STOPS SEE TIME TABLE

of his crew and for the completion of his mission, in exact accordance with his orders. The Captain's station is the left-hand pilot seat, during all take-offs or during approaches to airports, during landings and in all emergencies. An administrative station is provided for the Captain at an "office" at the rear of the flight deck. During the course of the flight he personally supervises all crew members, makes periodic checks of the navigation and prescribes speed, track and altitude of the aircraft.

The *First Officer* is second in command, after the Captain, and alternates with him as Senior Watch Officer. His qualifications are also second only to those of the Captain and he is usually a Senior Pilot qualified for early advancement to a Captain's rating. He is the executive officer of the ship. He is responsible for the proper loading and unloading of all cargo and for a thorough, general inspection of the aircraft before take-off. His primary station is the right-hand pilot seat.

FIG. 11.

The Flight Engineer's Station Aboard a Transatlantic Clipper.

Photograph shows the Flight Engineer at his station. Before him is his panel of instruments and controls from which may be checked or adjusted all elements of the aircraft having to do with power plant, fuel and mechanical accessories. At the extreme right is the bulkhead for the starboard companionway through the wing to the separate engine stations.

The *Second Officer*, who is a Senior Pilot-in-Training, is responsible for the navigation of the aircraft. Our navigation technique can best be described as "as thorough as we can make it." The navigation means available to this officer are three: dead reckoning, celestial observations and radio bearings. Our dead reckoning methods are basically similar to those used in deep sea practice. For some years, however, we have been using a drift sight target which, I believe, is original. It consists simply of a small thin-walled glass flask, filled with

pulverised aluminium powder. Breaking instantly upon impact with the water, it quickly produces a large and extremely visible " slick " to give a fixed point upon the water's surface. At night magnesium flares are used for the same purpose. Our celestial navigation practices are as streamlined as we can devise to speed the translation of octant sights upon sun, moon or stars into actual position data. Normally, celectial " fixes " are made at least once an hour and dead reckoning positions are computed between such " fixes " at least every half-hour. As a third method of checking the ship's position, the Navigation Officer makes constant use of radio bearings from direction-finder stations ashore taken on the plane or by bearings from the plane itself upon shore stations and ships at sea.

The *Flight Engineer* is responsible for the mechanical operation of the aircraft and the power plants. He is responsible for loading of fuel and oil in amounts specified by the Captain, and personally measures the supply of each aboard before departure. He also participates in the inspection and servicing of the plane and familiarises himself with its recent mechanical history. During the flight his station (Fig. 11) is aft and at the starboard side of the Flight Deck. At this station, the Engineer has before him his own control panel composed of some 41 separate instruments in addition to the engine throttles, carburettor settings, fuel supply valves and other power plant adjustments. These instruments provide him with a constant and complete record of all the various details of the ship's mechanical performance. As a testimonial to the exactness of his work, I may cite the fact that the Flight Engineer's Log, at the end of a typical transatlantic round trip, contains some 7,300 notations covering periodic reports on every phase of the ship's mechanical operations.

The *Flight Radio Officer* is responsible for the operation of the plane's complete radio equipment and for maintenance of constant communication with the radio-control stations ashore. On duty he is a rather busy airman. At a minimum, he must contact his watch-ground station every fifteen minutes. On the half hour he must transmit the ship's position and on the hour, in addition to the position, a complete report on its navigation and progress, the track made good, winds, weather and general conditions. He constantly receives weather reports, bearings from ground stations and is in turn himself taking radio bearings upon surface stations or upon any available ships within range.

Radio equipment carried by a Clipper consists of two completely interchangeable telegraph and telephone transmitters, which can operate on either high or low frequency, thereby providing for communication with surface vessels as well as the ground control stations. The ship also has two receivers, the function of which are interchangeable, and which cover frequency bands of 200 to 18,000 kilocycles. There is also an automatic direction finder which can be manually operated. An additional receiver for radio telephone operation, controllable from the pilots' posts, is carried for use within 60 miles of terminal stations, in conjunction with the regular transmitters. For communications, ground control stations are equipped with from three to five transmitters, of various power outputs, for ground-to-plane and point-to-point communications, together with the necessary receiving equipment. Each station, in addition, is usually equipped with radio navigation facilities. Normal communication ranges are in the neighbourhood of 3,600 miles.

The *Flight Steward*. Finally, in our enumeration of the Multiple Crew we come to the Flight Steward. His duties include responsibility for all details related to the comfort of passengers, such as the serving of meals, the preparation of berths, and the handling of luggage aboard ship. With sometimes as many as thirty-two passengers to care for, in addition to the crew, he is by no means the least busy member of the ship's complement.

The *Third Officer*, who is a Junior Pilot-in-Training, serves primarily as relief for the Second Officer during flight. Prior to take-off, he assists the First Officer in his inspection and has a duty of his own to make sure that all hatches and

10/13/39 PAN AMERICAN AIRWAYS COMPANY.

PAN AMERICAN AIRWAYS COMPANY. 10/13/39

ATLANTIC DIVISION.

OPERATIONS.

WATCH HOUR SCHEDULE.

G.T.C.	22.00	23.00	00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Captain	A			A	A	A		A	A		A	A				A	A	A	A			A	A	
First Officer	B	A	A			B	A		B	A			A	A	A	B				A	A			A
Second Officer	N	N	N	N	N				N	N	N	N	N	B				N	N	N	N	N		
Third Officer					B	N	N	N		B	B			N	N	N	N				B	B	N	N
Fourth Officer.		B	B	B			B	B				B	B		B		B	B	B	B			B	B
Engineer Officer	C	C			C	C			C	C			C	C	C	C					C	C		
Asst. Eng. Officer.			C	C			C	C			C	C					C	C	C	C			C	C
Radio Officer	D	D			D	D			D	D			D	D	D	D					D	D		
Asst. Radio Officer			D	D			D	D			D	D					D	D	D	D			D	D

1st Steward, 2nd Steward } Intermittent Continuous Duty.

Trip No. 313.

Date—May 13-14, 1941.

A—In Charge of Watch.
B—First Officer.
C—Engineer Officer.
D—Radio Officer.
N—Navigation.

FIG. 12.

The Watch Chart for the Multiple Crew.

Indicating the assigned hours of work and relief for each individual member of the standard flight crew of eleven which mans a transatlantic Clipper.

bulkhead doors are closed. Immediately after take-off, he conducts a visual examination of major external structural components and reports his findings to the Captain. He handles the bow mooring line when casting off and mooring. The *Fourth Officer*, also a Junior Pilot, assists the pilot officers in both flight and ground duties.

The Multiple Flight Crew is rounded out by an Assistant Flight Engineer, an Assistant Flight Radio Officer, and an Assistant Flight Steward, whose duties are obvious from their titles (Fig. 12).

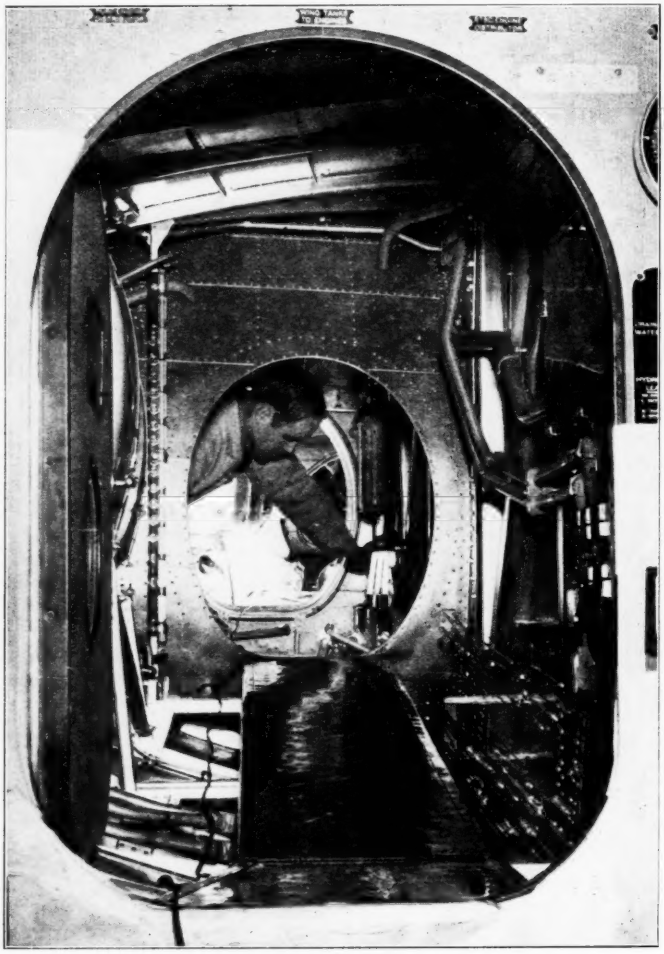


FIG. 13.

Wing Companionway to the Engine Stations.

Through companionways in the wing, each of the four engines is accessible for inspection by the Engineering Officers. From engine stations in each nacelle, the "work end" of the engine, with its electrical and fuel lines, are accessible for adjustment or repair in flight. From this companionway all fuel lines, control cables and the entire interior of the wing also are readily reached.

II. Accessibility of Power Plants.

In any flying operation sustained engine power is a necessity. In trans-ocean transport it may well prove critical. In order to reduce the risk of power failures we have considered for years that the accessibility of power plants in flight would be of inestimable value. It was not, however, until our latest type of Clippers were developed that manufacturers indicated that they could, without serious detraction from design plan, incorporate this feature.

The Boeing B-314 aircraft is provided with a companionway (Fig. 13) on each side of the Flight Deck leading through the wing to separate stations in the nacelles of each of the four engines. Although we have not won our point entirely, the entire engine not yet being accessible, these stations do provide swift access to the accessory end of each motor. Through these engine stations the Flight Engineer makes periodic visible inspection of the mechanical functioning of the aeroplane's engines and its delicate electrical, fuel and oil system. He also has available for his required and periodic inspection all main fuel lines, all control lines and all interior elements of the wing.

I have no way of quantitatively measuring the value of the accessibility thus permitted. But I can tell you that during the past two years, in which this type of Clipper has been in operation, on both the Atlantic and the Pacific, we have had 431 cases of repairs made in flight. The affected power plants were kept going or else quickly returned to operation. In 64 of these cases, had the engines not been accessible, the causes of the failures were of such a serious nature that the ship would have been forced to return to its nearest base with only three of its engines in operation.

The safety advantages of power plant accessibility are obvious. The savings of each such flight completed on schedule—compared with the total loss of revenue-production in a schedule failure—is in itself an economic factor of considerable importance. This record, we feel, requires that power plant accessibility will be in future specifications for ocean air transport aircraft.

III. Scientific Control of Flight.

Ocean air transport is the most exacting of all flight operations. Given the most expert crews and the perfect functioning of all mechanical elements, ocean transport flying, with equipment now available, must be carried out with a high degree of accuracy or it cannot succeed.

As a margin for safety, to care for any circumstances which may not have revealed themselves through pre-flight study of conditions, we require each trans-ocean Clipper of the Boeing B-314 type, when used on flights of 2,000 miles or over, to depart with sufficient fuel, based on the foreseen conditions, to arrive at its destination with a fuel reserve adequate for an additional 4½ hours of flying. This reserve fuel load is a constant factor in all flight-weight computations. What we call the " actual fuel load " is computed after thorough analysis of all foreseeable conditions which the plane must encounter on its planned crossing. Obviously, only after the fuel load is determined, and the mail poundage is provided for, can we arrive at a figure for the allowable passenger and cargo capacity for that particular flight.

From any standpoint, the most critical element of ocean flying is fuel consumption. Adequate fuel is an obvious requisite for the safe arrival at destination. Efficient utilisation of that fuel determines the efficiency of the flight itself.

How the Atlantic is Flown.

The manner in which this is accomplished is described under the general term of " Scientific Control of Flight." Briefly, this is a process by which the most efficient performance of the aircraft is charted through the most favourable conditions available to that flight. How we undertake to make this process

one of scientific accuracy may best be explained by describing the construction of an actual transatlantic crossing.

For this example, I have selected at random an average schedule—the Yankee Clipper, whose eastbound flight, on May 13-14, is designated as No. 313 in the operating records of our Atlantic Division. The New York to Bermuda stage and the Horta to Lisbon sector are short range operations and contribute no particular problems. The records I have used are devoted, therefore, to the Bermuda-Horta flight, which represents the critical sector of this route.

This particular Clipper had returned from Lisbon to New York on May 11 (Fig. 14). In the two days intervening before its departure, a staff of 185 mechanics including some 19 inspectors, operating through three eight-hour shifts, had performed work on and checked some 1,500 separate items required by our maintenance routine. Originally, this process consumed six days. Our present ability to effect it in two days is an important item in our ability to secure an efficient factor of aircraft utilisation.

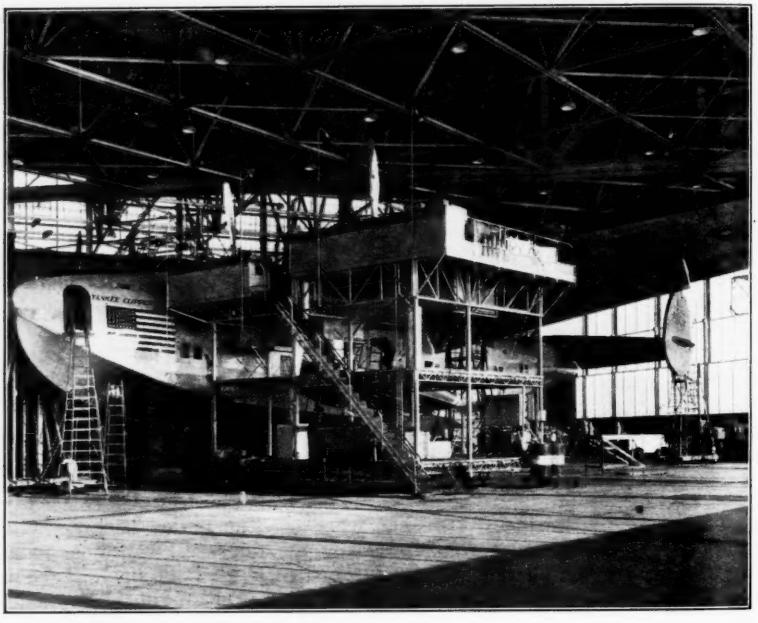


FIG. 14.

A Transatlantic Clipper Ashore.

Ready for a "quick turn-around"—a complete inspection and servicing routine which is accomplished in two days by a force of **185** *mechanics working in three* **8**-*hour shifts.*

Before the beginning of each crossing, the crew assigned for that particular transatlantic flight, accompanied by maintenance and service engineers, inspectors and mechanical specialists, puts the ship through a test flight on which air speed and all fuel-flow indicators are calibrated and all compasses are carefully compensated.

It is not until the aircraft, as finally tested, has been accepted by the Captain, that the Plan for the flight is formulated. The first step in this process is the final weather map, which represents the application of the most modern air-mass

methods of weather analyses to transatlantic flight problems. Supplementary to this general chart are upper-air weather maps reporting conditions at altitudes of 5,000 and 10,000 feet. A third chart (Fig. 15) represents a new departure. It is a third-dimensional or vertical weather chart, drawn to provide the pilot with an illustration of what conditions he is to expect and to illustrate the clouds, rain, fog, and icing areas forecast on the route.

From these charts, the meteorologist divides the projected flight line into various zones. Each zone represents an area of more or less consistent winds and the lengths of each are dependent upon the location of the various pressure areas and weather fronts along the route. These zone boundaries indicate the points at which a new track for the aircraft or a new flight level should be selected. From this map and the supplementary charts, the meteorologist then prepares a Flight Forecast (Fig. 16).

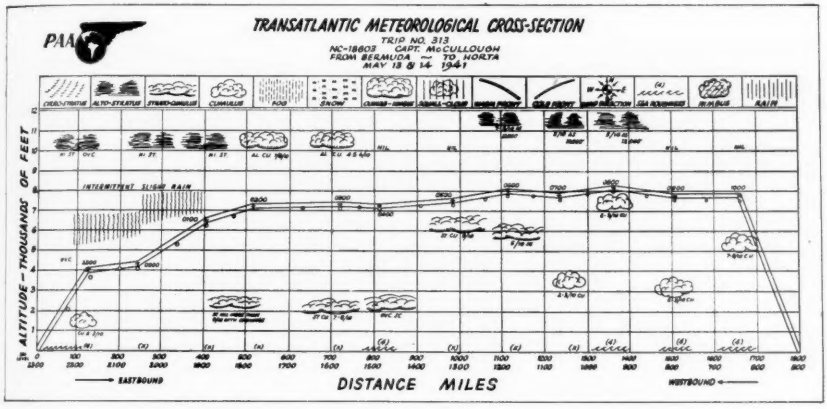


FIG. 15.

Pan American Three-Dimensional Weather Chart.

This forecast is supplementary to the basic weather map and the upper air map from which all flight forecasts are made. It provides the Captain with a visual description of conditions forecast for his crossing.

This reports the state of the weather, the amount, type and height of clouds, the estimated level at which freezing temperatures might be encountered, and wind direction and velocity at 1,000, 4,000, 8,000 and 12,000 feet. In addition, the meteorologist forecasts conditions at the point of destination and all alternates; gives such pertinent information as the location of fronts, the turbulence to be expected in such frontal areas, and points out any icing conditions which are likely to be encountered.

From this Flight Forecast the Captain and the Airport Manager evolve the Flight Time Analysis (Fig. 17). This process considers the complete range of the mechanical ability of the aircraft to the conditions to be encountered or to be detoured either laterally or vertically in each zone. The Flight Time Analysis for the route is calculated for each of the four " primary " altitudes by the use of a computer which quickly gives the ground speed through each zone, determined from the wind, air speed and track projected through that zone. From these ground speeds the time required to pass through each zone and to complete the entire flight can be estimated.

From such computations a three-dimensional path of best conditions can be plotted for the flight, designed to yield the safest, most efficient speed, track, and

altitude for each sector of the route. With the establishment of such a path, an accurate plan of operation is determined. This is finally compressed into the estimated fuel consumption required for the completed flight from terminal to destination.

You will note that this Flight Time Analysis also includes a separate estimate of fuel consumption made for a possible three-engined operation. This three-engined operation data is used to determine our so-called " Point of No Return." Laymen are inevitably intrigued by this fatalistic expression. As a matter of fact it is merely a designation of that limit-point, before which any engine failure requires an immediate turn around and return to the point of departure, and

FLIGHT FORECAST

PAN AMERICAN
PAA AIRWAYS SYSTEM

COMMUNICATIONS DEPARTMENT – METEOROLOGICAL SECTION

ATLANTIC DIVISION

FILED
PLACE NBA
DATE MAY 13, 1941
MAP 1200 GMT

TO BRITAIR METEO BDA, PANOP PANMET HTA.

TRIP 313 NGD3 TRACK BDA HTA LBN DEPARTURE TIME 2100

STD. FORM A1-8

ZONE ENDING	STATE WEATHER	AMT. TYP. BASE LOWER CLOUD	TOP LOWER CLOUD	AMT. TYP. BASE UPPER CLOUD	FREEZING LEVEL	WINDS 1000 FT.	4000 FT.	8000 FT.	12000 FT.
700	SHWRS	7SC20	45	3AC100	120	S 12	SW 20	SW 18	WSW15
1300	CLDY	5CU20	40	NIL	110	SW 12	SW 18	SW 14	WSW12
1797	PTLY	4CU20	50	NIL	110	NW 12	NW 15	WNW 20	WNW18
2200	CLDY	6CU20	60	6AS100	110	NW 15	NW 16	WNW 24	WNW20
2500	CLDY	4SC25	45	4AC100	110	WNW12	NW 12	NW 16	NW16
2708	PTLY	3CU25	40	NIL	110	S 10	SSW15	SW 16	WSW14

TERMINAL WEATHER	STATE WEATHER	AMT. TYP. BASE LOWER CLOUD	TOP LOWER CLOUD	AMT. TYP. BASE UPPER CLOUD	FREEZING LEVEL	SURFACE WIND	VISIBILITY		
HTA	CLDY	5CU22	50	NIL	110	WNW 14	9		
LBN	CLEAR	NIL	NIL	NIL	110	S 6	15		

REMARKS: TERCEIRA SAME AS HTA STOP AVEIRO SAME AS LBN STOP COLD FRONT EXTENDS SLIGHTLY SOUTH OF ROUTE AND WILL CROSS ROUTE ABOUT 700 OUT MARKED BY SHWRS AND SCATTERED THUNDERSHOWERS WITH TURBULENCE MARKED THRU FRONTAL ZONE STOP FEW TOPS TO 120 STOP SHWRS IN AND UNDR LOWER CLDS FIRST ZONE STOP SECOND FRONT OF SLIGHT INTENSITY WILL CROSS TRACK ABOUT 2200 OUT STOP WEAK OCCLUDED FRONT ABOUT 2500 OUT STOP

REYNOLDS 1927

FIG. 16.

Pan American Transatlantic Flight Forecast Form.

The standard form used to translate the estimated flight time into zones of varying meteorological and wind conditions used in the development of the Flight Time Analysis.

beyond which such return is no longer practical. Fuel reserve practice insures the ability of the aeroplane to reach the port ahead on three engines in case failure should occur beyond that " Point of No Return."

Upon acceptance of the Flight Time Analysis by the Captain and Airport Manager, the First Officer determines what payload can be carried and computes the Weight-and-Balance Manifest. By this method he determines the location for all passengers and cargo so as to obtain the most favourable Centre of Gravity for the take-off, flight and landing. The Third Officer's duty is to assemble the various clearance manifests required by the governments along the route. The Flight Engineer proceeds with the fuelling and servicing of the plane, according to the detailed figures resulting from the Flight Time Analysis. The B-314s have a total tank capacity for 5,400 gallons of fuel. Operating gross weight on all long range flights is invariably 84,000 lbs.

PAN AMERICAN AIRWAYS FLIGHT TIME ANALYSIS

Dist.	Track	1000 ft. Three Engines A.S.	G.S.A.	Time	A.S.	G.S.	Time	1000 ft. Wind	A.S.	G.S.	Time	4000 ft. Wind	A.S.	G.S.	Time	8000 ft. Wind	A.S.	G.S.	Time	12000 ft. Wind	A.S.	G.S.	Time
700	72	107	117	6.00	106	6.60	SW-12	121	131	5.35	SW-20	125	143	4.90	SW-18	131	147	4.77	WSW-15	136	150	4.67
1300	80	107	117	5.13	107	5.60	SW-12	122	132	4.55	SW-18	126	140	4.39	SW-14	131	142	4.22	WSW-12	135	146	4.11
1797	86	107	115	4.32	99	5.03	SW-12	123	130	3.82	SW-15	126	135	3.68	WSW-20	131	149	3.34	WSW-18	135	151	3.29
CLIMB FACTOR TO BE ADDED TO FIRST ZONE-										.01				.04				.12				.24
							Totals			13.73			Totals	12.91			Totals	12.45			Totals	12.31

End of Zone	Time Ahead		Fuel Cons. Ahead	Time Return	Fuel Cons. Return	Altitude	Ground Speed	Contact Intermediate Point	Time through zone	Total Fuel at end of zone	Fuel consumed	Fuel aboard comm.
0		10.9	2170		26.30	4320						4320
700	6.00	16.9	3070	6.60	19.70	3460	8000	147		4.89	4.89	5400 / 1110 / 3210
1300	5.13	22.0	3760	5.60	14.1	2660	8000	142		4.22	9.11	10950 / 71899 / 2421
1797	4.32	26.30	4320	5.03	8.8	1810	8000	149		3.34	12.45	13350 / 72523 / 1797

5.765

PAN AMERICAN AIRWAYS COMPANY
ATLANTIC DIVISION
FLIGHT PLAN
A FLIGHT TIME ANALYSIS

Ship NC 18603 Captain McCullough
Trip No. 313 Date May 13-14 1941
From NYA To: FOA
Forecast based upon 1200 GMT Hdg
Forecast issued at GMT

Cruising condition Long Range

$$t = \frac{16.2 \times 118}{144 + 118} = 8.20 \text{ (dry tanks)}$$

Time to arrive at point of no return

$$t = \frac{\text{Hours @ air S.G.S. back}}{\text{G.S. ahead + G.S. back}}$$

ALTERNATE Terceira

$$t = \frac{13.7 \times 118}{144 + 118} = 6.17 \text{ (4.5 hrs. res.)}$$

a. 6.122
4/3/40
00 copies

Navigator _____ Captain _____

12.45 Flight Time | 2523 Fuel consumed | 1797 Fuel reserve

FIG. 17.

Pan American Flight Time Analysis.

Computations based upon the weather map are translated in terms of a third dimensional path plotted to assure utilization of most favourable conditions for each scheduled flight.

After all the technical data has been compiled, as a last check on crew co-ordination a crew meeting is held immediately before departure, to review with each member the positions of all emergency equipment on the aircraft and an individual recitation drill is held on the correct procedure for each man for all emergencies, both in the air and on the water.

PLANNING A TRANSATLANTIC FLIGHT.

We are now ready for our departure. The take-off is accomplished with the Captain controlling the throttles and control surfaces, and the First Officer manning the flaps and the short-range radio telephone to the stand-by launch. During the take-off the Flight Engineer constantly checks cylinder head temperatures and oil and fuel pressures. Take-off power is 1,550 horse-power per engine at 2,400 revolutions per minute. The manifold pressure is 42½ inches. Take-off under normal conditions requires approximately 30 seconds from the time full power is applied until the aircraft leaves the water, after a run of approximately one-half mile. After the take-off the aircraft is held immediately above the water until an air speed of 105 knots is reached at which point full manœuvrability of the ship on three engines is assured. The engines are then pulled back to 1,200 horse-power each. This output is maintained by the Flight Engineer until all obstacles in the area are adequately cleared, generally at a height of 500 to

1,000 feet. At this point the engines are again throttled back to their climbing horse-power of 900 horse-power and speed of 110 knots maintained until the selected cruising altitude is reached.

Once aloft, the Flight Deck routine is conducted strictly in terms of the mechanical conditions imposed by the Flight Time Analysis which, in turn, are based upon the tabulated analysis of the performance of the aircraft under the given combination of circumstances. It becomes a primary duty of the Captain to study the reports of his Second Officer and Flight Engineer for any indication of conditions which might require modification of that flight plan. Any variation of the power plants or accessories, beyond certain prescribed limits, are immediately to be noted. Track made good compared with the projected course is also indicative, as are any serious variations in forecast weather.

Against this background of estimated and actual progress of the flight the Captain endeavours at all times to keep the aircraft flying under our standard long-range cruising formula, at its most efficient airspeed, that is, at the speed which will give the maximum miles of ground speed progress per gallon of gasoline consumed. As the gross weight diminishes, in ratio to fuel consumed, he must therefore continually reduce the power output in order to maintain, at all stages of the flight, the wing's most efficient angle of attack. At the end of this particular flight, for instance, the Flight Engineer's Log shows that the speed of the engines was successively cut to 1,200 revolutions per minute as the aircraft approached Horta. Because the gear reduction between the engine and propeller is 16 to 9, the propellers' revolutions per minute under this condition are reduced to approximately 675, at which speed the 14 foot 10 inch propellers appear to be moving very slowly indeed.

The "Howgozit Curve."

Thus is each transatlantic flight planned and conducted, but all the planning in the world would be useless unless it is executed with accuracy. To execute a plan accurately, it is necessary to have in hand an easily usable yardstick of performance. We have developed such a yardstick, which bears the very American title of a "Howgozit Curve" (Fig. 18). I might warn you here, that this is no mere pilot's nickname. It has now become a formal designation for this type of chart by our engineering department.

The "Howgozit Curve" was developed by our ocean captains under the leadership of Captain Harold Gray, now Chief Pilot of our Atlantic Division. Its purpose is to present to the crew aloft and the flight watch ashore a continuous flow of information as to the fuel reserve remaining aboard the aircraft and the fuel required for completion of the flight to destination, or back to the point of departure. Actually, it consists of five curves which are required to clearly present this picture. Using the path selected in the Flight Forecast and performance charts for the plane and its engines, a curve of miles vs. gallons is plotted, showing normal four-engined fuel consumption for the flight in hand. The second curve shows gallons vs. hours of flying. The third curve is of hours vs. miles. Since we must assume that three-engined operation may be made necessary at any time, the fourth and fifth curves, showing miles vs. gallons are also plotted for three-engine "ahead" and "return" conditions. Also on the chart at this time is plotted the "Point of No Return," which I have previously mentioned.

All of these curves I have so far mentioned, are drawn in solidly to indicate that they are based on the Flight Time Analysis. As the flight proceeds, a constant record of the plane's actual fuel consumption is maintained. It is the First Officer's duty to draw alongside these solid forecast curves, dotted curves which indicate the actual performance of the plane. Deviations to one side or the other simply and quickly indicate to the Captain, as well as to the Flight Watch Officer at the terminal, whether the flight is proceeding satisfactorily, or

whether some factor, such as changing wind condition, is raising the fuel consumption, and at what rate that fuel consumption is being raised. Just as importantly, the chart is of extreme value in forming any decisions as to the desirability of modifying, at any point, the track, the altitude, or of actually breaking off the flight for a return to the point of departure.

The flight I have described is purely typical from a technical viewpoint (Fig. 19). Other flights, of course, have had to consider other weather, wind and altitude factors. Some have plotted and executed detours of several hundred miles in mid-ocean to avoid predicted areas of high intensity storms. One flight on the mid-Atlantic Route in mid-winter actually made its scheduled crossing of a few minutes less than 24 hours in the teeth of head winds which averaged 41.9 miles per hour for the entire course. Each flight, I can safely say, has made some contribution to our technical knowledge of the Atlantic and its exacting conditions in this first two years of service.

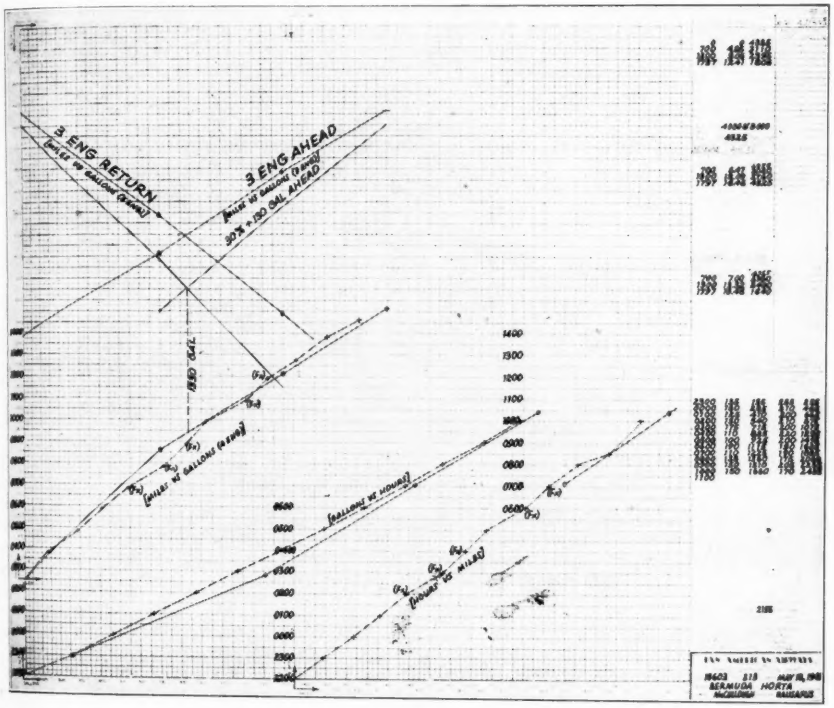


FIG. 18.

The "Howgozit Curve"—Comparing Forecast and Actual Flight Performance.

The unique graph by which constant check is made for the information of the Captain on the flight, and the Chief Watch Officer ashore, of the critical details of each transatlantic flight.

But despite these difficult conditions, we feel that the transatlantic airline has rendered an important service. Individual mail loads of 13,000 pounds and passenger loads in addition to mail of thirty-three eastbound and thirty-five westbound have been transported. We are particularly gratified that, although the war has transferred to the aeroplane some thirty per cent. of the total trans-

atlantic mails, our service has been able to carry all offered us by the postal authorities. Furthermore, the Clippers have consistently transported representatives of government and industry whose missions were of importance to your country as well as to our own.

PROBLEMS—AND AIRCRAFT TO MEET THEM.

Nor during this period has Pan American been unmindful of its responsibility to carry forward the further development of this trans-oceanic service. Hardly had our initial schedules been instituted with the 84,000-pound Boeing B-314 Clippers when specifications were released to manufacturers inviting their bids on the design and development of a new type of Clipper which our experience indicated to be the required next step in trans-oceanic development. Construction contracts for such aircraft were actually let in June, 1940, with the first deliveries scheduled for early 1942.

I regret that I am not yet at liberty to disclose, here or at home, the technical details of these aircraft. I can, however, cite certain of the immediate and specific problems encountered in our transatlantic operation, the presence of which we had in mind in their procurement.

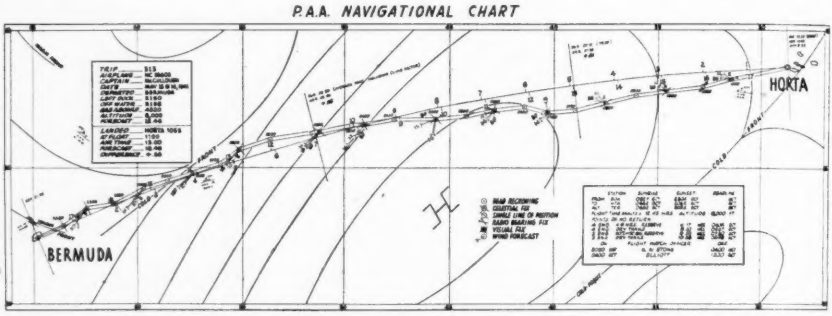


FIG. 19.

A Section of a Pan American Navigational Chart.

Imposed on the isobar lines of dominant weather, the actual track of the aircraft indicates the course flown in avoidance of weather areas or to take advantage of helping winds, and shows the principal celestial, radio and dead-reckoning position "fixes." The chart also shows a ready comparison with the Great Circle.

1. During the months between October 1st and April 1st, sea-swells in the harbour of Horta exceeded three feet on 35 days out of each hundred, and exceeded two and one-half feet on 57 days out of each hundred. The effective solution of this cause of delayed schedules is an advancement of the practical commercial range of trans-oceanic aircraft so as to permit the continent-to-continent non-stop operation.

2. The consistently high velocity of westerly winds, particularly during the winter months, contributes not only to schedule cancellations but even when such flights are technically feasible, impose unreasonable restrictions on payload. Wind aloft records maintained through the past two years indicate that higher cruising speeds of at least 75 to 100 miles an hour greater than those now available are desirable.

3. Finally, the recurring ice problem on the North Atlantic coast points to the advantages of landplane operations. Landplanes could also permit direct service between metropolitan airports on both sides of the Atlantic.

NEED FOR CONTINUED RESEARCH.

Let me emphasise once more that the aircraft of which we are now awaiting deliveries, are by no means anything which I would think of offering as " the ideal " transatlantic aircraft. It will be many years before depreciation and not obsolescence will be our concern. We have immediately before us advancing researches in such fields as boundary layer control, exhaust heat utilisation, and unorthodox power plants—to mention just a few.

Substantial advancement of ocean air transport, however, is by no means dependent upon further revolutionary developments. Refinement of details are productive of far-reaching results. The need for efficiency distinguishes a long-range ocean transport from other civil aircraft. For example, the latest type short-range landplane, the Douglas DC-3, can make a flight of 750 miles, with forty-five minutes' fuel reserve, carrying a full load of twenty-one passengers. For such a normal assignment this aeroplane carries a fuel load of 450 gallons, weighing 2,700 pounds, which represents only 11 per cent. of its gross weight, or 33 per cent. of its useful load. By comparison the Boeing 314 operating over a route of 2,400 miles, with 4½ hours' fuel reserve, requires 4,000 gallons or 24,000 pounds of fuel, which constitutes 29 per cent. of its gross weight and 73 per cent. of its useful load. If some means can be found to increase the efficiency of the DC-3 by one per cent., this would increase its payload by only 27 pounds. If a corresponding increase of one per cent. could be made in the efficiency of the Boeing 314, however, we would gain no less than 240 pounds, or slightly more than the allowance for one passenger. Effort and expense are continuously justified for research whereby such efficiency improvements can be achieved.

CONCLUSION.

Of one thing we can be sure in this uncertain world—the advance of aircraft design is in dynamic forward motion. We can, I feel, look forward to wing loadings of 80 pounds; aspect ratios of 11; useful-to-gross weight ratios of 50 per cent. Efficient three thousand horse-power engines are in prospect. With advances such as these in the offing, who would be bold enough to predict the distant future?

In these past two years transatlantic passenger service has already become a fact. It is no longer an adventure. It has become a vital link between the new world and the old.

Before the next two years have passed, I believe we can, with confidence, look forward to frequent daily flights, operating on twelve-hour schedules to bridge what was once a great barrier ocean and to bring our two great democracies into still closer union.

Mr. GRIFFITH BREWER (*Hon. F.R.Ae.S., President*): It was his privilege to propose a vote of thanks to the lecturer. Before he did that, he would read three cables which had been sent and received concerning this lecture.

The first, addressed by the speaker to Mr. Orville Wright, ran as follows:—

" Dear Orv.—On the Seventeenth June, as President of the Royal Aeronautical Society, I am to welcome Juan Trippe, who is coming to deliver the Wilbur Wright Memorial Lecture. I have been flown home to receive your distinguished countryman. You would greatly please me if you would further honour the Royal Aeronautical Society with a Cable Greeting to be read at the meeting to my Council and Members."

To which Mr. Wright replied:—

" That the Royal Aeronautical Society and Mr. Trippe take the time now to hold the Wilbur Wright Lecture is a tribute to Wilbur's memory not to be expected in strenuous times such as these. I am deeply appreciative.

Greetings to Mr. Trippe and my heartiest good wishes for the welfare of each and every member of the Society."

A further telegram had been received from Mr. Lester Gardner, Executive Vice-President of the Institute of the Aeronautical Sciences, U.S.A. :—

"*Greetings from Institute Aeronautical Sciences to Royal Aeronautical Society and Juan Trippe. May ocean air transport be of increasing aid to our common aims in present crisis, and in future bring better understanding and goodwill among peoples of the world.*"

Continuing, the speaker said that the Wilbur Wright Memorial Lecture was founded twenty-nine years ago, as a permanent memorial to the work of Wilbur and Orville Wright. Orville Wright, the younger brother, still lived near Dayton, Ohio, where for thirty years past the speaker had spent part of each year with him and had met his smiling face at the breakfast table. He was keenly interested in this lecture.

The lecture was delivered one year by an Englishman and the next by an American, and this succession had gone on unbrokenly for twenty-nine years. He felt they were extremely fortunate to have Mr. Trippe for this "American" year. The lecture was a bond between the two countries, and far more than an aeronautical bond. It meant a friendship between the English-speaking nations, which would endure long after the combined British-American effort had resulted in victory.

It gave him, therefore, very great pleasure to propose the vote of thanks, and he would ask Lord Sempill to second it.

Lord SEMPILL: Mr. Chairman, Your Excellency, Ladies and Gentlemen,—As the President has said, the Wilbur Wright Memorial Lecture is unique and its importance cannot be over-stressed. The Royal Aeronautical Society—now half-way through its seventy-sixth year and by far the oldest society in the world dealing with aeronautical science, aeronautical engineering and the art of air pilotage—invites each year one of great distinction to honour the memory of the first man to fly in a power-driven aeroplane.

There can be no question but that this distinction could not have fallen to one better qualified to speak, by virtue of his outstanding achievements in that realm of aeronautical development. He whose memory they honour to-day was the great pioneer of this work, and he and his brother (who is still working) devoted the whole of their genius to the furtherance of this same realm of aeronautics, so nobly represented by our lecturer to-day. Too much importance cannot be given to this occasion, which is but one link in the many that bind the United States of America and the British Empire together for a common purpose.

No one other than he who now sits there could occupy the chair. The first British subject to pilot an aeroplane and thus pay a practical tribute to the work of Wilbur Wright, he, a one-time President of our Society, appears before us for the first time as the Minister of Aircraft Production, and they congratulated him and themselves, and know that he looks to America and, like Oliver Twist, "asks for more."

The proposer of the vote of thanks which he had the high honour to second, is also the only man worthy of the task. As the first is Irish and the second English, a great compliment to the Scots is implied.

Two years before the speaker was born, the proposer of the vote of thanks was flying, and since then it has been impossible to keep him out of the air—whether in balloons, airships, or aeroplanes. When the Wright brothers first landed in Europe he was there, and was the first British passenger to fly in an aeroplane. At the beginning of the last war, he was under the instruction of Mr. Orville Wright in his flying school in America. There he took his ticket. After the 1914-1918 war was over he was one of the first to join the newly-formed Flying Club Movement and was a very active member. Some ten years ago

he bought his first aeroplane, and only the stringent orders of His Majesty's Government, forbidding all civil aviation at the beginning of this war, kept him on the ground.

This restriction greatly irked him and he was not to be denied. He was anxious to be with them all in honouring the memory of his old friend, and so celebrated the fiftieth anniversary of being in the air by flying back from Canada in one of those splendid American aircraft that are so much appreciated by both flying services.

They had listened to a vivid and intensely interesting description of the activities of Pan American Airways in spanning the oceans, but his purpose is to say something about one whose personal contributions to this great development had only been touched on by the Chairman and the proposer of the vote of thanks. The building up and operating of this unique organisation provides beyond any question the most notable and successful technical and operational development in world commercial aviation. The design and building of air stations in all parts of the world—South America, China—not forgetting the coral atolls in the Pacific—with the hangars, slipways, floats, repair shops, wireless and meteorological units, and, most vital, the negotiating of landing rights in foreign countries, is as complicated a business as is to be found in any form of transport.

The task has required immense vision, a supreme tact and unremitting hard work and a tremendous faith in the rightness and eventual realisation of the plan.

Pan American Airways was started some years after the other great national air transport companies had been in operation. In this way, much was learned from the successes and failures of others.

In 1927 the company started operating a hundred-mile route between Key West and Havana, but within three years was operating some 18,000 miles, and to-day some 66,000 miles, maintaining contacts with South America, China, Australia, New Zealand, Alaska, and the Old World. This is nearly 16 per cent. of the world air route mileage, of which approximately a half is flown by this and the other American air transport companies.

Pan American Airways does not operate within the confines of the U.S.A. It is the chosen instrument of the United States Government and operates over more route miles than any air transport company in the world, showing the Stars and Stripes on the air trade routes to a greater extent than any American shipping company does at sea.

Some idea of its activity may be gauged from the fact that in the last thirteen years the United States Post Office has paid more than half its gross revenues to the company, although, as would be natural, a good portion has been returned as stamp revenue.

Pan American Airways may be likened to one of the great chartered companies built up in the reign of the Stuarts, as, for example, the Hudson Bay Company.

Mr. Trippe, the leaders of aviation in all its phases are here to honour the memory of Wilbur Wright, and, by so doing, to acclaim you as one of the outstanding figures in aviation in the United States—nay, more than that, in the world of aviation—for through you has come this great development of mechanical flight that his genius made possible.

The Secretary of State for Air has asked that it be made known how deeply disappointed he is at not being able to be present, being detained at a Cabinet meeting.

Rear-Admiral St. George Lyster, R.N., the Fifth Sea Lord and Director of the Naval Air Service and of the operational activities of the Coastal Command, R.A.F., recognises you firstly as one who has served in the Naval Air Service in the last war, and has since then done so much to advance the development of flying boats. In this tribute, Air Chief Marshal Sir Philip Joubert de la Ferté, R.A.F., Commander-in-Chief of the Coastal Command, joins.

The Director-General of Civil Aviation, Sir Francis Shelmerdine, the Hon. Mr. Clive Pearson and the Hon. Member Mr. Runciman, the chiefs of British Overseas Airways, salute you as the Founder and President of the world's greatest air transport company, alongside of which they are proud to operate.

Others in all spheres of aeronautical development pay a tribute to you for what you have done to advance long distance air transport. One who has been responsible for the design of our ocean-going flying boats, Mr. A. Gouge, should in particular be mentioned.

They owed a deep debt of gratitude to the people of America, and such cannot be said too often or more fittingly than on this particular occasion. Wilbur Wright never thought of aircraft for war purposes, but, like the father of British aviation, Sir George Cayley, thought only of the benefits they could bring to mankind.

There can be no doubt, however, that were he with them now, he would be the first to see that the genius of invention God gave to man should be used, in the words of the great Edmund Burke, speaking of a previous European cataclysm, to "extirpate this canker from the centre of Europe; otherwise it will spread to the extremities of the world with dire results."

Your coming some 3,000 miles for this occasion made a profound impression on them, and it is to be hoped that many in all spheres of activity in your great country will come over here and give, as you have done, of their advice to the full, and see what they were doing here. One needs your help, both in the sphere of technology and production.

He took it as a great honour to second this vote of thanks to Mr. Juan Trippe.

Following the lecture the Annual Council Dinner was held at which the following were present:—

Professor L. Bairstow, C.B.E., F.R.S., F.R.Ae.S., Zaharoff Professor of Aeronautics, Imperial College of Science and Technology (Vice-President of the R.Ae.S.); Captain H. H. Balfour, M.C., M.P., Under-Secretary of State for Air; Mr. Robert Blackburn, O.B.E., A.M.Inst.C.E., M.I.M.E., F.R.Ae.S., Managing Director, Blackburn Aeroplane Co., Ltd. (Member of Council of R.Ae.S.); Group Captain H. G. Brackley, D.S.O., A.F.C., Coastal Command, R.A.F.; Mr. Griffith Brewer, Hon. F.R.Ae.S., President of the Royal Aeronautical Society; Major J. S. Buchanan, C.B.E., A.M.I.M.E., F.R.Ae.S., Director General of Aircraft Production, Ministry of Aircraft Production; Mr. S. Camm, C.B.E., F.R.Ae.S., Chief Designer and Director, Hawker Aircraft Limited (Member of Council of the R.Ae.S.); Dr. H. Roxbee Cox, D.I.C., B.Sc., F.R.Ae.S., Deputy Director of Scientific Research, Ministry of Aircraft Production (Member of Council of the R.Ae.S.); Lieut.-Col. C. M. Cummings, Acting Military Air Attaché, American Embassy; Mr. W. C. Devereux, F.R.Ae.S., Managing Director, High Duty Alloys, Ltd. (Member of Council of the R.Ae.S.); Mr. E. C. Gordon England, F.R.Ae.S., Managing Director, General Aircraft, Ltd. (Member of Council of the R.Ae.S.); Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.I.Mech.E., M.S.A.E., F.R.Ae.S., Chief Engineer, Bristol Aeroplane Co., Ltd. (Past-President of the R.Ae.S.); Mr. A. Gouge, B.Sc., F.R.Ae.S., Director, Chief Designer and General Manager, Short Brothers, Ltd. (Member of Council of the R.Ae.S.); Major F. B. Halford, M.S.A.E., F.R.Ae.S., Technical Director and Chief Designer, Messrs. D. Napier and Son, Ltd., and Chief Designer (Engines), De Havilland Aircraft, Limited (Member of Council of the R.Ae.S.); Mr. J. E. Hodgson, Hon. F.R.Ae.S., Honorary Librarian, Royal Aeronautical Society; Captain Huskisson, R.N., Chief Technical Department, Fleet Air Arm; Captain A. G. Lamplugh, F.R.G.S., F.R.Ae.S., Underwriter and Principal Surveyor, British Aviation Insurance Co., Ltd. (Member of Council of the R.Ae.S., Hon. Treasurer of the Society); Colonel G. D. Larneer, Assistant Military Air Attaché, American Embassy; Colonel A. J. Lyon, U.S. Air Corps; Rear-Admiral A. L. St. George Lyster, Fifth Sea Lord, Admiralty; Lieut.-Col. the

Rt. Hon. J. T. C. Moore-Brabazon, M.C., F.R.Ae.S., M.P., Minister of Aircraft Production (Vice-President of the R.Ae.S.); Mr. T. A Monroe, Vice-President, Pan American Airways; Commodore R A. Ofstie, U.S. Navy, American Embassy; the Hon. Clive Pearson, Chairman, British Overseas Airways Corpn.; Mr. R. K. Pierson, M.B.E., B.Sc., A.M.Inst.C.E., Chief Designer, Vickers-Armstrongs, Ltd.; Capt. J. Laurence Prtichard, Hon. F.R.Ae.S., A.F.I.Ae.S., Secretary, Royal Aeronautical Society; Dr. A. G. Pugsley, A.F.R.Ae.S., A.M.I.Struct.E., Head of Aircraft Development Department, Royal Aircraft Establishment (Member of Council of the R.Ae.S.); Mr. D. R. Pye, C.B., M.A., Sc.D., F.R.S., M.I.Mech.E., F.R.Ae.S., Director of Scientific Research, Ministry of Aircraft Production (Member of Council of the R.Ae.S.); Mr. N. E. Rowe, B.Sc., A.C.G.I., D.I.C., A.F.R.Ae.S., Deputy Director of Research and Development of Aircraft, Ministry of Aircraft Production (Member of Council of the R.Ae.S.); the Hon. W. L. Runciman, D.F.C., Director General, British Overseas Airways Corpn.; Lord Sempill, A.F.C., F.R.Ae.S., Fleet Air Arm; Lieut.-Col. Sir Francis Shelmerdine, C.I.E., O.B.E., F.R.Ae.S., Director General of Civil Aviation, Air Ministry; Major C. J. Stewart, O.B.E., M.I.M.E., F.R.Ae.S., Director General of Production of Aircraft Equipment, Ministry of Aircraft Production; Mr. F. M. Thomas, A.F.R.Ae.S., Aero Engine Designer, Bristol Aeroplane Company (Member of Council of the R.Ae.S.); Mr. A. Hessell Tiltman, B.Sc., F.R.Ae.S., Managing Director, Airspeed (1934), Ltd. (Member of Council of the R.Ae.S.); Mr. Juan T. Trippe, President, Pan American Airways; Captain Turner, Assistant to Acting Military Air Attaché, American Embassy; Dr. H. C. Watts, M.B.E., M.Inst.C.E., F.R.Ae.S., Technical Director, Airscrew Company (Member of Council of R.Ae.S.); Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor to Royal Aeronautical Society; Mr. R. T. Youngman, B.Sc., F.R.Ae.S., Head of the Technical Department, Fairey Aviation Co., Ltd. (Member of Council of the R.Ae.S.).

REVIEWS.

THE ELEMENTS OF AERONAUTICS.

K. Schütt, Ph.D. Translated by E. Reissner and F. Fleetwood. Sir Isaac Pitman & Sons, Ltd. 1941. 12/6.

" The appearance, at this particular time, of a work translated from the German, may cause some surprise," say the translators. " We therefore wish to make it clear that all arrangements for its publication in England had been made before the outbreak of war, although its appearance has been delayed thereby. The German original was highly successful, and soon came to be regarded as one of the most useful works on elementary aeronautics that have been published in recent years."

" Here then is a serious work," continues the translators, " addressed to the air cadet, the mechanic or apprentice who wants to understand the reasons underlying his daily work, the senior schoolboy, the parent or teacher who, knowing little of aeronautics, is baffled by the perpetual ' why? ' of his young charges."

No apology is needed by the publishers or translators for the appearance of any book on engineering or science which is worth its salt. Both subjects are independent of national frontiers, although the use to which they are put may not be.

Whether the book will appeal quite so widely as the translators claim, however, depends entirely on the enthusiasm of those who are now taking such a big part in the war effort. Some will undoubtedly find it comparatively hard reading, although it is not beyond the intelligence of any reader who really wants to know something about his subject. It can be said without any reservation, that this book will enable anyone who is willing to learn to obtain an extremely good grasp of the way an aeroplane flies. That might be said of a considerable number of books now published, but the one under review has a number of advantages over others which make it well worth close study.

The author has made a special feature of outlining simple experiments, which the reader can try for himself, to test the statements made about air flow. These experiments are worth close study by teachers as well as students, for they give practical demonstrations of the peculiarities of air flow which will give a much clearer idea of why an aeroplane flies than most text books on aerodynamics do.

The author, too, constantly draws upon commonplace instances in other spheres to demonstrate his statements, as for example on the pressure of fluids in motion. If, for example, as the author points out, two ships pass near each other in calm water, they run the risk of collision, since the pressure decrease between them tends to pull them towards each other; or two boats lying close at anchor in a river are driven together because the speed of the water flowing between them is increased.

The chapter on boundary layer is another example of the author's simple explanatory methods. As he shows, anyone eating honey can easily demonstrate the existence of a boundary layer, or can see it clearly round boats and ships.

Some of his experiments, as those showing fluid pressure, the lift of a wing (by means of a hair drier and a postcard!), the Magnus effect, the action of a tail plane, the magnitude of the pressure generated inside an engine and others would in themselves form a delightful lecture for young air enthusiasts and teach

them more about why an aeroplane flies than many lectures of a more formal nature would.

One repeats that for those who really wish to learn something about the why and wherefore of flight this book can be thoroughly recommended.

THE AEROPLANE OF TO-MORROW.

N. Pemberton-Billing. R. Hale, Ltd., 1941. 12/6 net.

This forecast is written by one major prophet, N. Pemberton-Billing, and one minor prophet, Roger Tennant. The minor prophet is described by the major as a disciple of theory with a " young but intelligent brain applied to the theory of aeronautics over a period of five years." No description of the major prophet is given by the minor one, in the book. The probable reason is that Pemberton-Billing baffles description. But the minor prophet has undoubtedly written the major part of the book.

The Aeroplane of To-morrow is, in effect, a treatise on the virtues of high-wing loading and assisted take-off. What admitted vices high-wing loading has, are easily swept away by the authors, by the use of slip-wing. The slip-wing is a glider attached to the upper surface of the aeroplane to relieve the high-loading at the take-off. On reaching a suitable height, the glider is released. It may be fitted with a low-powered engine to give the pilot more opportunity to choose a suitable landing ground.

The authors look upon wing-loadings of 70 to 100 lbs. per sq. foot as practicable now, and consider loadings up to 300 lbs. per sq. foot as theoretically possible, though even they boggle at the thought of landing with this loading. It is definitely doubtful whether " by a combination of assisted take-off and power-controlled landings, stalling speeds will be kept at their existing values despite take-off loadings of 100 lbs. per sq. foot and landing loadings of 70 lbs. per sq. foot."

The authors outline a long-range bomber, the P-B49, which will make other designers sit up and think. What they think the reviewer may guess! The PB-49 has a bomb load of 10,000 lbs., a range of 5,000 miles, and a cruising speed of 400 m.p.h. The total all-up-weight will be 41,660 lbs., wing loading 98 lbs. per sq. foot, and horse-power 4,000. By using a slip-wing, the loading for take-off is reduced to 32 lbs. per sq. foot, and by using up the fuel and bomb load, the landing loading is reduced to 40 lbs. per sq. foot.

In case of a sudden emergency landing, following the release of the slip-wing, it is hoped the bombs can always be released where they won't do any harm, that fuel can be jettisoned as rapidly and that an aerodrome is available for a forced landing. Anywhere else with even 40 lbs. per sq. foot, will not be every pilot's dream of a happy landing.

Chapter II deals at length with the need for high wing loading. The authors consider the possibilities of aerodynamic, power and structural improvements.

" From all of which," they assert, " it can be seen that the increase in speed for the future that is likely to be obtained by aerodynamic improvements is not very great. . . . Equally, it has been demonstrated that neither are improvements in engines or structures likely to provide great increases in performance. Only one of the contributory factors remain in wing loading."

If the only future advance lies in greater and greater wing loading, then the aeroplane of the future is going to be even more dangerous than it has been to land or take off, slip-wing or no slip-wing. There will be considerable competition to be a slip-wing pilot.

A good case can be damned by over-statement. The major author has a knack of over-statement which makes one accept with caution any statement he may make. He has a brilliant imagination, but the polish wears off in practice.

On page 30, Mr. Pemberton-Billing claims to have got off the ground in 1908 for sixty feet in a monoplane. To quote his own words: "*Flight's* representative, after examining the wheel tracks in the grass with a magnifying glass, verified that it was the first occasion on which a British aeroplane had left the ground."

This almost might have been called the Flight of To-morrow, as Flight was only founded in January 1909.

On page 91, the author, writing about the publication of Dr. Lanchester's aerofoil theory in 1907, adds "which is two years before anyone flew in this country." Dates should be consistent in any one book.

On page 32, the major author claims that *Aerocraft*, which he founded at the end of 1908, was the world's first aviation journal. A visit to the Society's library would enable him to study a number of aviation journals founded many years before 1908.

It is unfortunate that the author rushes into print as easily as he used to rush about the country in one of his famous cars. He has the enthusiasm of the dragon-fly, darting here and there, and rousing from time to time the admiration of non-critical observers, but like the dragon-fly he does not appear to be capable of a long-range flight.

The reviewer has no intention of damning this book with faint praise, but he wonders after reading it, what The Aeroplane of To-morrow will be like and, also a busy commercial aerodrome; how the slip-wings will fit in with the organisation. The wing area of a slip wing to reduce a 75 lb. per sq. foot aircraft, considered on page 244, from 75 lbs. to 20 lbs., will be such that there will be greater difficulties of landing on a busy aerodrome than even the imagination of the author has visualized.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES,

OCTOBER, 1941.

Council Meeting.

A Meeting of Council was held in the Offices of the Society on Wednesday, September 17th, 1941:—

Present: Mr. Griffith Brewer (President) in the chair; Mr. S. Camm, Dr. H. Roxbee Cox, Mr. A. H. R. Fedden (Past-President), Professor F. T. Hill, Dr. A. G. Pugsley, Dr. D. R. Pye, Mr. A. Hessell Tiltman, Dr. H. C. Watts, Mr. L. A. Wingfield (Solicitor), Mr. R. T. Youngman.

Among the business discussed was the following:—Reports on Sunday Discussions and other discussions; Report of the Grading Committee; summary of the meeting on the Future of Civil Aviation.

Election of Members.

The following members were recently elected:—

Associate Fellows.—Harold Bucklow, Maurice Arthur Frank Hirst (from Student), George Patrick Lefroy Pardoe.

Associates.—John Lindsay Bennett, Edward Jonathan Crow, Eleanor Lettice Curtis, Norman Ramsden, William Findlay Matthew Stenhouse, Edgar Alexander Wright (from Student).

Graduates.—Idris G. Bowen, Robert Skinner (from Student), Frederick Vere Kent Sutton.

Students.—Philip Maciver Archer, Raymond Frederick Creasey, Herbert Roy Hadley, John Gareth Frank Lang, Robert Arthur Letts, Harold Keith Quilter, John Gordon Ross, Owen Gordon Thetford, Jack Joseph Ward, John Cecil Wimpenny.

Companions.—Hon. Clive Pearson, Julius Wolmark.

President.

Mr. Griffith Brewer, Hon. F.R.Ae.S., commences his second term of office of President on October 1st, 1941.

Amy Johnson Memorial Fund.

The following donations have been received for the Amy Johnson Memorial Fund from members of the Society:—

	£	s.	d.
Miss F. M. Buss (Companion)	1	1	0
Mrs. Walker Sinclair (Companion)	1	1	0
Mr. R. E. Cunningham (Associate Fellow) ...	0	5	0

Acknowledgments.

The Council acknowledge with grateful thanks the following gifts from members of the Society:—

Mr. Griffith Brewer—Valuable historical pamphlets, books, photographs, etc.

Mr. J. E. Hodgson—Journals of the Society.

Mr. Geoffrey Smith—N.A.C.A. Reports and Technical Notes and a series of foreign magazines and publications.

Miss Betts—Journals of the Society and books for the Library.

Additions to the Library.

Pamphlets in italics, with location reference following in brackets.
Books marked * or ** may not be taken out on loan.

A.a.283.—The Internal Work of the Wind. S. P. Langley. Smithsonian Institution. 1893.

A.a.290.—Experiments in Aerodynamics (2nd Ed.). S. P. Langley. Smithsonian Institution. 1902.

A.a.291.—Applied Aerodynamics. L. Bairstow. Longmans and Co. 1920.

B.a.248.—*Transatlantic Flight by Vickers-Vimy-Rolls Aeroplane (with Description of the Machine). Reprint from "Engineering," June 20th, 1919. Vickers, Ltd.* 1919. (Y.3.ii.V.)

B.c.56.—Sailplanes. C. H. Latimer Needham. Chapman and Hall. 1932. (*Posted as missing: now returned to the Library.*)

B.c.57.—*Der Segelflug: eine neue Flugtheorie. Gustav Lilienthal. Article in "Glasers Annalen für Gewerbe und Bauwesen," April 15th,* 1921. (Y.10.c.3.)

*B.g.106.—*Aircraft Identification, Part III (Italian Fighters, Bombers and Seaplanes). "The Aeroplane" (Temple Press, Ltd.).* 1941. 2/-. (PB.5.)

*B.g.107.—*Aircraft Identification, Part IV (American Types for the R.A.F.). "The Aeroplane" (Temple Press, Ltd.).* 1941. 2/-. (PB.5.)

*B.g.108.—*American Aircraft for Service with the Royal Air Force and Fleet Air Arm. Hutchinson and Co.* 1941. 1/3. (PB.5.)

BB.b.91.—The Design of Screw Propellers for Aircraft. H. C. Watts. Longmans and Co. 1920.

BB.f.43.—General Instrument and Oxygen Equipment. (A.P.388.) The Air Ministry. H.M.S.O. 1921. 5/-.

C.c.59.—*The Steering of Balloons. D. Biddle. Lecture before the Balloon Society of Great Britain, Oct. 8th,* 1880. (PR.1/2a.)

C.d.143.—*Dirigible Balloons and Flying Machines. Thomas Fraser. The Victorian Institute of Engineers.* 1899. (PR.1/3b.)

C.d.144.—*The Zeppelin Airship. Thomas E. Curtis. Smithsonian Institution, Washington. (Reprint No.* 1,270.) 1901. (Y.30.ii.)

D.f.35.—Relazione finale della Commissione d'Inchiesta sull'Incidente dell'Apparecchio S.64 pilotato dal Ten. Colonello A.A.R.N. Umberto Maddalena. (Supplement to "Rivista Aeronautica," August, 1931.)

E.b.86.—Columns. E. H. Salmon. Henry Frowde and Hodder and Stoughton. 1921. 21/-.

*E.c.21.—*Investigation of Thin-Walled Beams with Unparallel Strips. A. Romashersky. C.A.H.I. Transactions No. 203. Moscow. ...1935. (R.T.P. Translation No.* 1,264, *September,* 1941.)

G.e.A.73.—The Heat Treatment of Aluminium and its Alloys. Research and Development Bulletin of the Northern Aluminium Co., Ltd. June, 1941.

I.a.20.—Aircraft Mathematics. S. A. Walling and J. C. Hill. Cambridge University Press. 1941. 2/9.

J.g.186.—*The Relation of the Wind to Aerial Navigation. A. L. Rotch. Reprint from the Aeronautical Annual.* 1910. (PJ.1.b.1a.)

J.g.187.—*The Ice Age Problem. Walter Knoche. Smithsonian Institution, Washington. (Miscellaneous Collections, Vol. 99, No. 22.)* 1941. (Y.30.i.)

L.a.41.—The Complete Flying Course. N. Roy Harben. C. Arthur Pearson. 1938. 6/-.

L.b.38.—Practical Flying in War and Peace. Albert H. Munday. Musson Book Co., Toronto. 1940. $3.

L.c.21.—The Harben Course on the Link Trainer. N. Roy Harben. Air Schools, Ltd., Derby. 1939. 7/6.

M.b.44.—*The Morse Code (Learning and Practice). R. G. Shackel. Longmans, Green and Co.* 1941. 1/-. (PM.2.c.6.)

*Q.a.142.—The Reference Library of the Welding Research Council. Section 1. Classified Library Catalogue. Institute of Welding. 1941. 2/-.

Q.d.49.—*15th Report from the Select Committee on National Expenditure (Session 1940-1941). House of Commons. H.M.S.O.* 1941. 2d. (PQ.1.b.11.)

**P.a.159.—Five Patents Relating to Aviation. (U.S.A. Nos. 922, 709—922, 713.) James Means. U.S. Patent Office. 1909.

**R.b.221.—L'Air et le Monde Aérien. Arthur Mangin. Alfred Mame, Tours. 1865.

**R.b.222.—Collected Aeronautical Papers of Lawrence Hargrave (1893-98).

R.b.223.—*Aerial Navigation. O. Chanute. (Reprint of Lecture to Sibley College, Cornell University, May 2nd, 1890.) Railroad and Engineering Journal, New York.* 1891. (PR.1/3a.)

R.b.224.—*Lord Rayleigh on Flight. Smithsonian Institution. (Reprint No. 1,268.)* 1901. (Y.30.ii.)

R.c.259.—*Sir Hiram Maxim's Apparatus at Thurlow Park. (With inset picture.) Privately printed.* 1904. (PR.1/9a.)

R.c.260.—*Benjamin Franklin and the First Balloons. A. L. Rotch. Davis Press, Worcester (Mass.).* 1907. (PR.1/13b.)

R.c.261.—*The Problem of Flight. José Weiss. King, Sell and Olding.* 1908. (Y.11.ii.a.8a.)

R.c.262.—*Dirigible Balloons in Warfare. H. A. Julliot. Junior Institution of Engineers.* 1908. (PS.1/8a.)

R.c.263.—*Researches and Experiments in Aerial Navigation. S. P. Langley. Smithsonian Institution, Washington. (Reprint No. 1,809.)* 1908. (Y.30.ii.)

R.c.264.—*What Clément Ader did. Wilbur Wright. Aero Club of America Bulletin, May,* 1912. (Y.11.ii.a.39.)

R.s.265.—*The "Hovering Machine" as an aid to Scouting in War. James Ram. Privately printed,* 1900. (PS.14a.)

R.d.39.—*Some Interesting Facts and Photographs. Dayton Wright Airplane Co.* 1918. (PR.2/18.)

R.e.46.—*An Achievement. (Booklet describing the development of the Wright Aeroplanes.) Dayton Wright Airplane Co.* 1919. (PR.2/19.)

R.f.70.—*Photostat of Chapter XI: "Flight" from book "Australia Advances," by David M. Dow (Funk and Wagnalls, about 1933), and further extract (pp. 157-159) on Hargrave Models.* (PR.3/9a.)

RR.111.—Principles of Flight. (2nd Ed.) Algernon E. Berriman. "Flight" Publishing Co. 1911.

S.a.121.—Textbook of Naval Aeronautics. Henry Woodhouse. T. Werner Laurie. 1918.

S.e.28.—The Northern Garrisons. Eric Linklater. H.M.S.O. 1941. 6d.

S.e.29.—Fighter Pilot (Anonymous.) B. T. Batsford. 1941. 6/-.

T.a.89.—*Leaders of Britain in the Royal Air Force. Capt. A. O. Pollard. Hutchinson and Co.* 1940. 6*d.* (PT.1/N.)

T.b.76.—Woman and Flying. Lady Heath and Stella Wolfe Murray. John Long. 1929. 12/6.

*T.c.39.—The Northward Course of Empire. Vilhjalmur Stefansson. Harcourt, Brace and Co. 1922. (Autographed.)

*T.c.40.—*The Polar Airship. Walter Wellman. National Geographic Magazine.* 1906. (*With handwritten letter from the author to Major Baden-Powell.*) (Y.11.ii.a.7a.)

UL.6.—*Aeronautical Research Institute, Tokyo Imperial University: Reports*:—

No. 202. Acoustical Studies of the Flutter of an Airscrew—Experiments with actual Airscrew. (Investigations of Airscrew Flutter, Part II.) J. Obata, Y. Matumura, R. Kanayama and Y. Yosida. 1940.

*UU.c.—*National Advisory Committee for Aeronautics. Technical Memoranda*:—

No. 979. General Airfoil Theory. H. G. Küssner. (From Luftfahrtforschung, Dec., 1940.)

*UU.f.—*National Advisory Committee for Aeronautics. Miscellaneous Papers*:—

No. 46. Protection against Acoustical Shock in Radio Earphones. J. A. Becker.

WB.1/16.—Flying. (Quarterly Magazine published by Iliffe and Sons.) June and September, 1902.

WB.21.—Journal and Proceedings of the Royal Society of New South Wales. Vol. LXXIV, Part 3. 1941.

*X.b.136-140.—Royal Aero Club: Year-Book, 1909 and 1913 editions. Rules and List of Members, 1906, 1908-9, 1910.

Y.24.—*Publications of the Tin Research Institute*:—

No. 105. The Spectrographic Analysis of Tin-Lead Solders. D. M. Smith. 1941.

J. Laurence Pritchard, *Secretary and Editor*

A NOTE ON THE LIMITATIONS OF AIRCRAFT AND AEROFOILS USED FOR HIGH FLYING AIRCRAFT.

By J. A. C. Williams, Grad.R.Ae.S.

The formation of shock waves as a limitation in aircraft design has been considered only, as far as the author knows, in the cases of wing sections at low operating lift coefficients and of the airscrew efficiency. There is, however, a further limitation for high flying aircraft in that the small air density causes

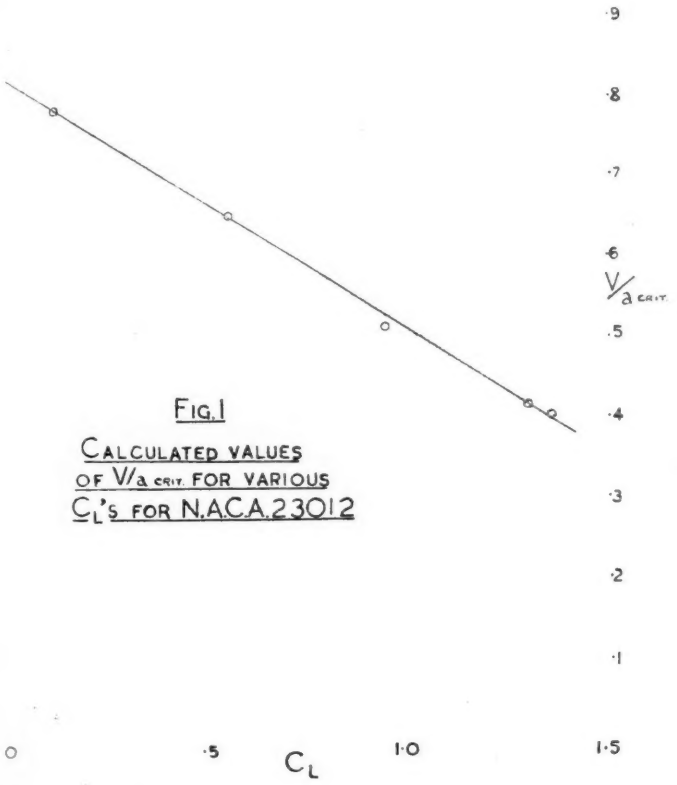


FIG. 1

CALCULATED VALUES OF V/a crit. FOR VARIOUS C_L'S FOR N.A.C.A. 23012

the aircraft, even at the stall, to travel at a value of Mach number (V/a) which will cause a shock stall to form on the wing. In some cases the aircraft will be able to prevent this shock stall at high C_L by flying faster, but in others, due to high wing loading, the wing sections will be shock stalled at all C_L values and the only remedy will be to decrease the wing loading.

The value of the Mach number (V/a_{crit}) at which a shock wave is formed on some part of the aerofoil surface, for any given t/c and centre-line camber distribution, depends upon t/c_{max} and the incidence (or C_L) of the section. Generally it is true, that V/a_{crit} decreases with increase of t/c_{max} and also increase of angle of incidence. It is this latter effect that imposes the limitation considered here.

The variation of V/a_{crit} with C_L has been calculated, making a simplification for the N.A.C.A. 23012 section (see Appendix), and is plotted in Fig. 1. The slope of the curve, from physical reasoning, would probably increase with

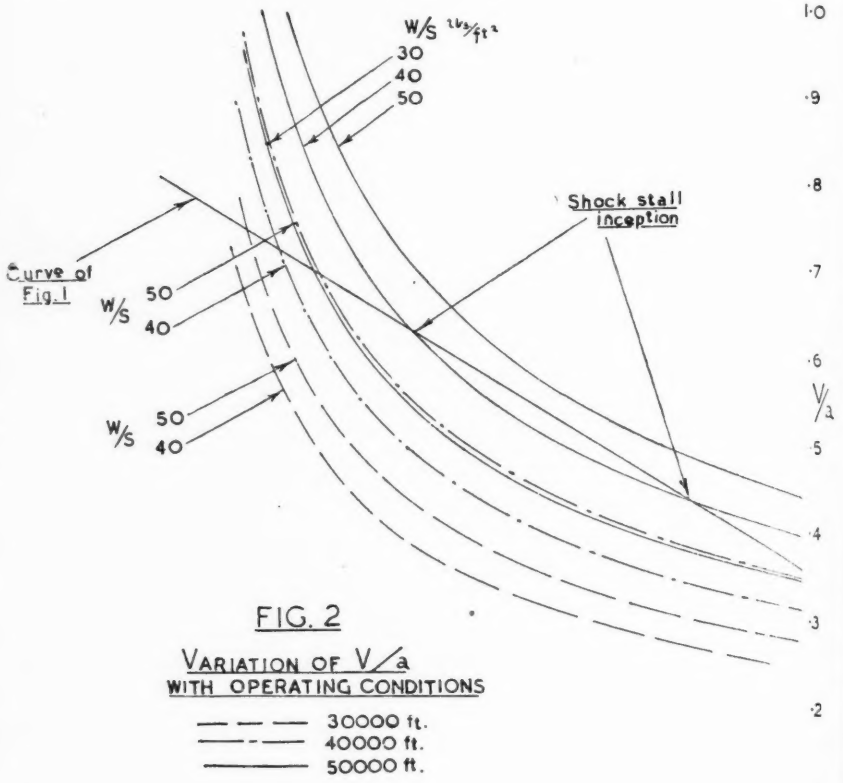


FIG. 2

VARIATION OF V/a WITH OPERATING CONDITIONS

decrease of t/c_{max} ratio, so that although, say at C_L 0.2, V/a_{crit} is numerically greater for a t/c_{max} of 4 per cent. than for a t/c_{max} of 12 per cent., at C_L 1.0 it is probable that the position will be reversed, due to the greater slope of the curve in the former case.

If the operating V/a of an aircraft, assumed having the wing section of Fig. 1, be above the curve, the wing section will be shock stalled. Now the operating

value of V/a for an aircraft—derived from the fundamental weight-lift relationship and the value of the speed of sound " a " at the given height—is :—

$$V/a = \left(\frac{W/S}{\frac{1}{2}\rho C_L}\right)/a \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

which gives a family of curves of the type shown in Fig. 2. These curves cut the curve of Fig. 1 in two places, if part of the working range of C_L for the aircraft is not shock stalled, one at high C_L and the other at low C_L. The latter case has been the case that has received attention from the absolute speed record point of view, but the former case will engage the mind of those designing high ceiling, high performance aircraft.

The curves of Fig. 2 have been prepared from Eq. 1 for various wing loadings and heights (values of ρ and " a ") and the curve of Fig. 1 has been superimposed upon them. This shows that at the high C_L end of the speed range the N.A.C.A. 23012 section will not have shock stalled at values of W/S of 50 lb./ft.^{2} and a height of 40,000 ft., but that at a height of 50,000 ft. the maximum permissible wing loading will be in the region of 40 lb./ft., due to the high C_L shock stall. As conjectured earlier, it is possible that the use of a thicker section will relieve the position at the high C_L end of the range, which will react favourably on the ceiling and rate of climb in that it will permit a greater aspect ratio to be used.

The author has not sufficient data to prepare any other curve for Fig. 1 than that for N.A.C.A. 23012, but it is possible to calculate the necessary values for any type of aerofoil section by the use of Theodorsen's method (see Ref. 1 and Appendix), but the method is laborious. In any case, such calculations are only of indicative value because the V/a_{crit} value for an aircraft wing depends upon the aerofoil section fabrication limits, any small dent or bump forming a potential formation point for a shock wave.

Appendix.

The values of V/a_{crit} for Fig 1 have been calculated from the low V/a pressure distribution for the aerofoil (Ref. 2). A simplification has been made in that the flow around the aerofoil has been assumed the same for compressible as for incompressible or low V/a conditions, and the isothermal form of Bernouilli's equation has been used to determine V/a_{crit}. From this, if V be the speed of the stream at infinity and "a" the speed over the aerofoil surface at the point where the shock wave is formed, then

$$V/a_{crit} = \frac{1}{\sqrt{\{1 + (P_o - P)/(\frac{1}{2}\rho v^2)\}}} \quad . \quad . \quad . \quad . \quad (2)$$

The value of $(P_o - P)/(\frac{1}{2}\rho v^2)$ is obtained from the pressure distribution diagram as the maximum suction value, *i.e.*, where the local velocity is a maximum. This approximation is excusable in that first, the flow over an aircraft wing is necessarily of three-dimensional form whereas the wind tunnel pressure test is two-dimensional, secondly, the manufactured wing is far from perfect, and finally because of the labour involved in taking compressibility into account.

References.

1. N.A.C.A. Tech. Report No. 411: " Theory of wing sections of arbitrary shape." T. Theodorsen.
2. N.A.C.A. Tech. Report No. 633: " Pressure distribution over an N.A.C.A. 23012 airfoil with a slotted flap and a plain flap."

BUCKLING OF PLATES WITH LATERAL STIFFENERS.

By Huang Yushan.

In most of the problems concerned with the buckling of plates it is assumed that the length of the plate is greater than its width, and that the edges of the plate, at which the compression loads are applied, are simply supported. The method of support of the side edges vary with the actual conditions.

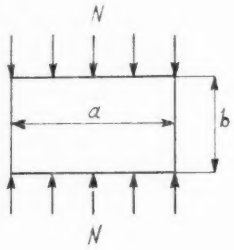


Fig. 1.

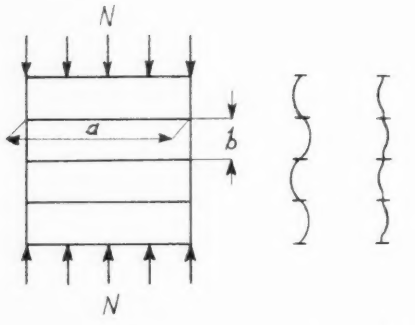


Fig. 2. 2A. 2B

In the case of short wide plates or plates with many lateral stiffeners, as shown in Figs. 1 and 2 respectively, the effect on the buckling load due to the conditions of support at the two side edges will become less, and that due to the conditions of support at the end edges will become important, so that they can no longer be assumed to be simply supported. For ease of calculation the side edges are assumed to be simply supported.

From the theory of plates ("Theory of Elastic Stability," Timoshenko) the differential equation for a buckled plate is

$$\frac{\partial^4\omega}{\partial x^4}+\frac{2\,\partial^4\omega}{\partial x^2\partial y^2}+\frac{\partial^4\omega}{\partial y^4}=-\frac{N}{D}\frac{\partial^2\omega}{\partial y^2} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where ω represents the displacement normal to the $X-Y$ plane, N the compression load per unit width in the Y direction, $D=Eh^3/12(1-\mu^2)$, h the thickness of the plate, and μ Poisson's ratio.

The displacement ω may be expressed in the form of Fourier's series

$$\omega=\sum_{m=1,2,3\ldots\infty} F_m(y)\sin\frac{m\pi x}{a} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where $F_m(y)$ is a function of y only. This expression satisfies the assumed boundary conditions $d^2\omega/dx^2=\omega=0$ at the edges $x=0$ and $x=a$.

Substituting in (1) from (2) we have

$$\sum_m\left[F_m''''(y)-2\left(\frac{m^2n^2}{a^2}-\frac{N}{2D}\right)F_m''(y)+\frac{m^4\pi^4}{a^4}F_m(y)\right]\sin\frac{m\pi x}{a}=0 \quad . \quad (3)$$

Since (3) must hold for any value of x between 0 and a, the fourth order differential equation of $F_m(y)$ given in the bracket must also be zero.

Solving it, we have

$$\omega=\sum_m\left[C_1\cosh\alpha_m y+C_2\cosh\beta_m y+C_3\sinh\alpha_m y+C_4\sinh\beta_m y\right]\sin\frac{m\pi x}{a}. \quad (4)$$

where

$$\alpha=\left\{\frac{m^2\pi^2}{a^2}-\frac{N}{2D}+\left(\frac{N^2}{4D^2}-\frac{m^2\pi^2N}{Da^2}\right)^{\frac{1}{2}}\right\}^{\frac{1}{2}}$$

$$\beta=\left\{\frac{m^2\pi^2}{a^2}-\frac{N}{2D}-\left(\frac{N^2}{4D^2}-\frac{m^2\pi^2N}{Da^2}\right)^{\frac{1}{2}}\right\}^{\frac{1}{2}}$$

When $N/D\geqslant 4m^2\pi^2/a^2$, α and β are imaginary and when $N/D<4m^2\pi^2/a^2$, both are complex.

The expression for ω in (4) is an infinite sine series, but as the load approaches the critical value the term $F_n(y)\sin n\pi x/a$ becomes predominant. Physically this means that the plate buckles into n half-waves in a lateral direction. From experience it is known that $n=1$ gives a minimum value of the buckling load, so only the first term in the series is considered in the following.

From the conditions of support at $y=0$ and $y=b$ four simultaneous equations may be obtained to determine the four constants in (4). Since there is no load normal to the XY plane, $C_1=C_2=C_3=C_4$, which means the plate remaining flat, unless the determinant of the four simultaneous equations is zero. Buckling of the plate can only occur when this determinant is zero, therefore, and from it the buckling load may be calculated.

EXAMPLES.

Consider a plate supported by a number of lateral stiffeners with equal spacing as shown in Fig. 2. The flexural rigidity of the lateral stiffeners is assumed to be infinitely great and the torsional rigidity equal to $2D$. The plate will buckle in the symmetrical form shown in Fig. 2*a*.

The boundary conditions for an elastically built-in edge can be written

$$-D\left(\mu\frac{\partial^2\omega}{\partial x^2}+\mu\frac{\partial^2\omega}{\partial y^2}\right)=C\frac{\partial^3\omega}{\partial x^2\partial y}$$

Since $\partial^2\omega/\partial x^2=0$ along the edge $y=\pm b/2$

$$D\frac{\partial^2\omega}{\partial y^2}=C\frac{\pi^2}{a^2}\frac{\partial\omega}{\partial y} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and $\omega=0$.

By symmetry $C_3 = C_4 = 0$ in (4).

From (4) and (5)

$$\begin{vmatrix} D\alpha^2 \cosh\frac{\alpha b}{2} - C\frac{\pi^2}{a^2}\sinh\frac{\alpha b}{2} & D\beta^2 \cosh\frac{\beta b}{2} - C\frac{\pi^2}{a^2}\sinh\frac{\beta b}{2} \\ \cosh\frac{\alpha b}{2} & \cosh\frac{\beta b}{2} \end{vmatrix} = 0$$

which simplifies to

$$\alpha \tanh\frac{\alpha b}{2} - -\beta \tanh\frac{\beta b}{2} = \frac{Da^2}{\pi^2 C}(\alpha^2 - \beta^2) \quad . \quad . \quad . \quad (6)$$

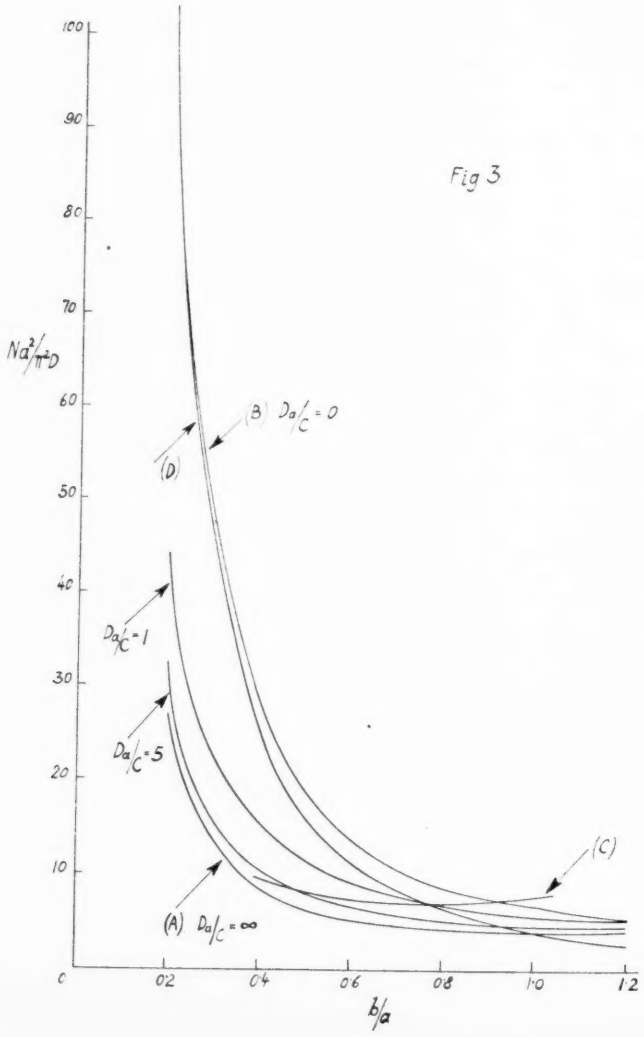
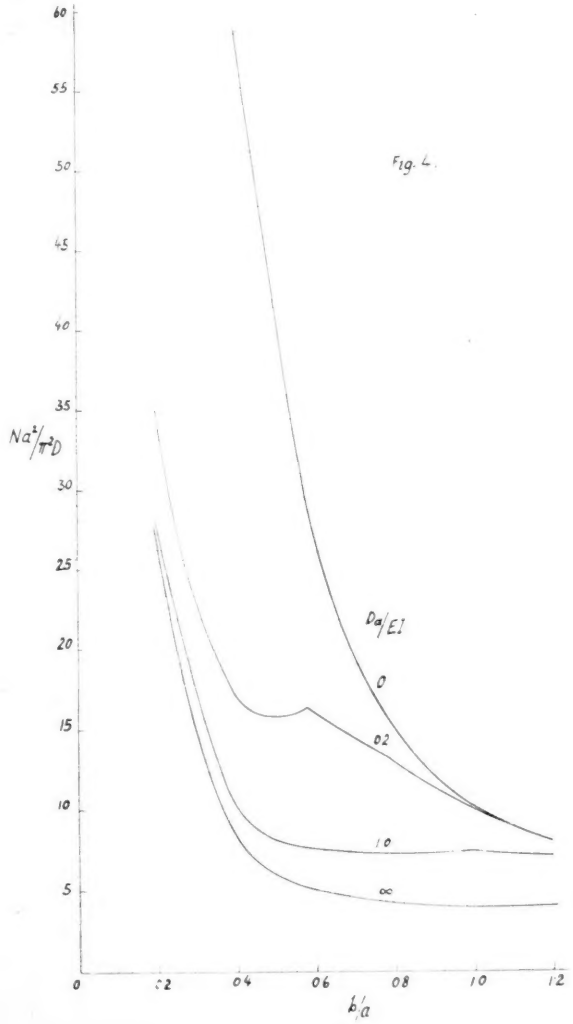


Table I gives numerical results of (6) and Fig. 3 plotted results. When Da/C approaches infinity or C approaches zero, we get curve A of Fig. 3, the well-known result for a simply supported plate. When Da/C approaches zero the two end-edges of the plate become built-in supports and the curve B of Fig. 3 is obtained. Curve B approaches curve A as b/a becomes larger, showing the



correctness of the assumption that the effect of the supporting conditions at the two end edges on the buckling load is negligible in the case of a long plate. For small values of b/a, curve B approaches curve D, the Euler buckling load of the plate, that is the buckling load of a plate free along its two side edges. It proves again that for a very wide plate, the supports at two side edges have little effect on the buckling load.

Curve C is the well-established result of the buckling of a plate with two fixed side-edges and two simply supported end-edges. A comparison of curves C and B shows that the fixing of the two side-edges when b/a is less than 0.89 gives a higher buckling load.

The horizontal line $Na^2/\pi^2D=4$ or $\alpha=\beta$, which satisfies Eq. (6), is a particular solution of the general differential equation and has no practical meaning.

In Fig. 2*b* a plate is considered in which the flexural rigidity of the lateral stiffeners equals a finite value EI, and the torsional rigidity may be neglected. It is assumed the plate will buckle in the form shown in Fig. 2*b*.

The boundary conditions at $y=\pm b/2$ can be written

$$EI\frac{\partial^4\omega}{\partial x^4}=D\left[\frac{\partial^3\omega}{\partial y^3}+(2-\mu)\frac{\partial^3\omega}{\partial x^2\partial y}\right] \quad . \quad . \quad . \quad . \quad (7)$$

$$\frac{\partial y}{\partial \omega}=0$$

From symmetry, $C_1=C_2=0$.

The determinant which gives the buckling conditions is therefore

$$\begin{vmatrix} D\alpha^3\cosh\frac{\alpha b}{2}-(2-\mu)\frac{\pi^2}{a^2}\alpha D\cosh\frac{\alpha b}{2} & -EI\frac{\pi^4}{a^4}\sinh\frac{\alpha b}{2} & \alpha\cosh\frac{\alpha b}{2} \\ D\beta^3\cosh\frac{\beta b}{2}-(2-\mu)\frac{\pi^2}{a^2}\beta D\cosh\frac{\beta b}{2} & -EI\frac{\pi^4}{a^4}\sinh\frac{\beta b}{2} & \beta\cosh\frac{\beta b}{2} \end{vmatrix}=0$$

which simplifies to

$$\frac{1}{\alpha}\tanh\frac{\alpha b}{2}-\frac{1}{\beta}\tanh\frac{\beta b}{2}=\frac{Da^4}{EI\pi^4}(\alpha^2-\beta^2) \quad . \quad . \quad . \quad (8)$$

The results of (8) are given in Table II and Fig. 4 from which the effect on the buckling load due to flexural rigidity EI of the stiffeners can be roughly seen. The curve $Da/EI=\infty$ is the same as curve A in Fig. 3, and the curve $Da/EI=0$ represents a buckled plate as shown in Fig. 2*b*. We can determine whether the plate will buckle in the form of Fig. 2*a* or 2*b*, and its buckling load N, of the size and thickness of the plate and the spacing and rigidity of its lateral stiffeners are known, by calculating the values of Da/C and Da/EI and reading the lowest value of Na^2/π^2D from Figs. 3 and 4. It should be noted that b in Fig. 4 is double that in Fig. 3. The solution becomes much more complicated if the plate buckles into any but these two symmetrical forms, or if the plate is anisotropic with many small longitudinal stiffeners.

TABLE I (Fig. 2*a*).

Values of Na^2/π^2D.

b/a	0.2	0.4	0.6	0.8	1.0	1.2
$Da/C=\infty$ (*A*) ...	27	8.4	5.1	4.2	4.0	4.1
$Da/C=5$	31	10.2	6.3	5.1	4.7	4.7
$Da/C=1$	43	15.5	9.1	6.8	5.8	5.4
$Da/C=0$ (*B*) ...	102	27.8	13.5	8.7	6.8	5.5
,, (C) ...	—	9.4	7.1	7.3	7.7	—
,, (*D*) ...	100	25	11.1	6.3	4.0	2.7

TABLE II (Fig. 2*b*).

Values of Na^2/π^2D.

b/a	0.2	0.4	0.6	0.8	1.0	1.2
$Da/EI=\infty$	27	8.4	5.1	4.2	4.0	4.1
$Da/EI=1$	28	10	7.6	7.3	7.5	7.2
$Da/EI=0.2$	35	17	16	13	10	8.0
$Da/EI=0$	—	59	27	15	10.2	8.0

National Advisory Committee for Aeronautics.

Technical Memorandum No. 948.

A SIMPLE APPROXIMATION METHOD FOR OBTAINING THE SPANWISE LIFT DISTRIBUTION.*

By O. Schrenk.

Preliminary Remarks.

In this paper a simple approximation method is presented for rapidly computing the lift distributions of arbitrary aerofoils. The numerical results are compared with those obtained by an exact method and for many purposes show a satisfactory degree of accuracy. The latter, for all practically occurring cases, can be estimated at the start of the computation work with the aid of the comparison examples given.

The method described below enables the approximate determination of the lift distributions in a few minutes with an accuracy sufficient for many purposes. It is also characterised by a certain simplicity which is useful in the clarification of many questions and is in accord with the engineer's point of view. Finally, the method is applicable to cases for which all other methods are entirely unsuitable (for example, wings with end plates).

Similar methods, as the author subsequently found, have already appeared elsewhere. The surprising accuracy of such simple methods is, however, generally unrecognised, so that a presentation of comparison computations which provide a measure of the degree of accuracy obtainable, should lead to an extended application of the method.

The author wishes to express his appreciation to his co-worker at Göttingen, Mr. N. Hiorth, for carrying out the laborious computations required for the comparison.

Fundamental Idea of the Method.

The plausible assumption is made that the real lift distribution lies between an ideal distribution independent of the wing shape and a distribution determined in a simple manner by the wing shape. The ideal distribution is that with minimum induced drag and constant induced downwash velocity—that is, for the usual monoplane, the elliptic distribution; while the distribution dependent on the shape is proportional to zt at each position of the wing.

Computation Procedure.

In the case of the untwisted wing the angle of attack is not absolutely necessary. There is drawn instead (for the monoplane) the semi-ellipse of equal area with the chord-distribution curve, and the lift distribution is obtained by forming the arithmetical mean between the two curves.

In the case of twisted wings (and similarly for wings with aileron or flap deflection) there is first determined the zero lift direction of the entire wing. A sufficient approximation for this is the direction of the mean aerodynamic twist

$$\bar{\delta} = \frac{\overline{\delta(x)\, t(x)}}{\bar{t}}$$

Where the bars denote mean values. $\delta(x)$ and $\bar{\delta}$ are the twist angles between the reference direction of the entire aeroplane and the local and mean zero lift

* "Ein einfaches Näherungsverfahren zur Ermittlung von Auftriebsverteilungen längs der Tragflügelspannweite." Luftwissen, Bd. 7, Nr. 4, April 1940, pp.118-120.

directions, respectively. For all further computations, the angles of attack and twist are reckoned from the zero lift direction given by δ.

With angles reckoned as indicated above, the lift is decomposed into a component without twist and a twist component without lift. The second component is determined on the basis of a mean value which has the zero line instead of the ellipse as the ideal distribution, and for which the twist angle must always be considered.

The general case with twist is most conveniently computed with the aid of the following formula, which requires no explanation:—

$$\frac{dA}{dx}=\tfrac{1}{2}\,q\,\frac{dc_a}{d\alpha}\alpha\left\{t\,(x)+\frac{4}{\pi}t\sqrt{\left[1-\left(\frac{x}{b/2}\right)^2\right]}\right\}+\tfrac{1}{2}\,q\,\frac{dc_a}{d\alpha_\infty}\delta\,(x)\,t\,(x)$$

In the above relation $dc_a/d\alpha$ and $dc_a/d\alpha_\infty$ can generally be taken as constant along the span. A somewhat more accurate formula is given below.

The trial computation of $dc_a/d\alpha$ and $dc_a/d\alpha_\infty$ may be somewhat refined by the introduction of a correction factor $(1+\kappa)$ setting:—

$$\frac{dc_a}{d\alpha}=\frac{\dfrac{dc_a}{d\alpha_\infty}}{1+\dfrac{dc_a}{d\alpha_\infty}\dfrac{F}{\pi b^2}(1+\kappa)}.$$

The constant κ for various taper ratios was determined by trial in such a way that the lift determined with our approximation method is given as correctly as possible (Fig. 1). In the case of the rectangular wing the value thus determined agrees with the theoretically determined value of Glauert. For other taper ratios the agreement has not been checked and in this connection is not required. A further refinement in the value of κ, nevertheless, seems unnecessary.

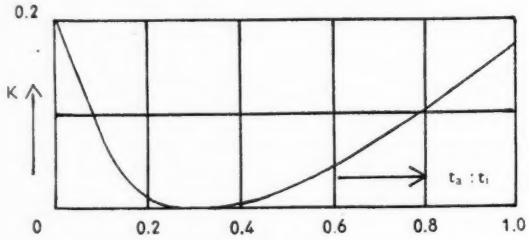


FIG. 1.

The values of κ that occur in the formulæ for dA/dx. For non-trapezoid shaped wings the nearest value of the taper ratio is used for the determination of κ.

The computation procedure thus consists of the following steps:—

(*a*) Computation of $\bar{\delta}$ by forming the mean.
(*b*) Trial computation of $dc_a/d\alpha$ and $dc_a/d\alpha_\infty$.
(*c*) Computation of the lift distribution by the formula for dA/dx.

ACCURACY OF THE METHOD.

The comparisons given in Figs. 2 to 13, between the accurate values computed by the method of Multhopp and the results of the approximation method, show in general a satisfactory, and to some extent even surprising, agreement. The error arising through the assumption of a constant value of $dc_a/d\alpha$ along the span in unfavourable cases, can be eliminated by computing a mean value

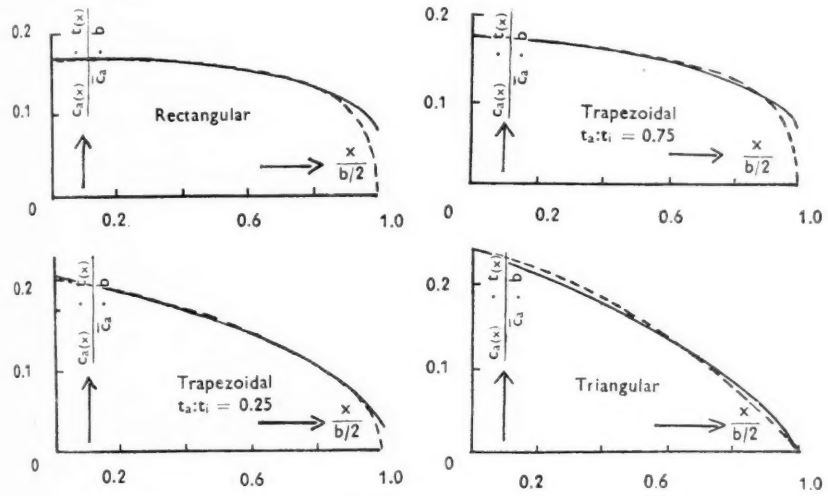
$$\frac{dc_a}{d\alpha_\sim}=\frac{\overline{\dfrac{dc_a\,(x)}{d\alpha_\infty}\,t\,(x)}}{\bar{t}}$$

and then computing the lift by the only slightly altered formula

$$\frac{dA}{dx} = \tfrac{1}{2} q x \left\{ \frac{dc_a(x)}{dx} t(x) + \frac{dc_a}{dx} \frac{4}{\pi} t \sqrt{\left[1 - \left(\frac{x}{b/2} \right)^2 \right]} \right\} + \tfrac{1}{2} q \frac{dc_a(x)}{dx} \delta(x)\, t(x)$$

The sharp difference between lift without twist and twist without lift, to be sure, no longer arises. This correction has not been applied in the example here given.

——— *Approximation.*
– – – – *Exact by Multhopp's method.*



FIGS. 2 TO 5.

Comparison curves with $b^2/F = 6.67$ for various taper ratios. The comparison for $t_a : t_i = 0.5$ is given on Fig. 6. No twist.

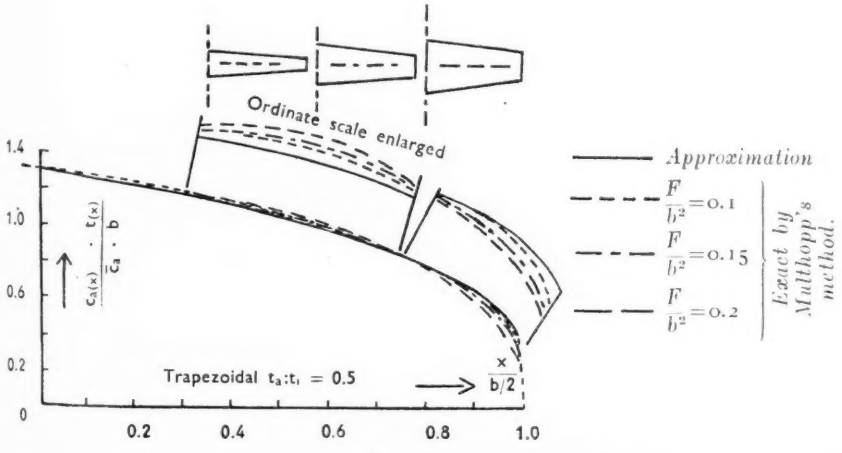


FIG. 6.

Comparison curves for $t_a : t_i = 0.5$ for various values of F/b^2. No twist.

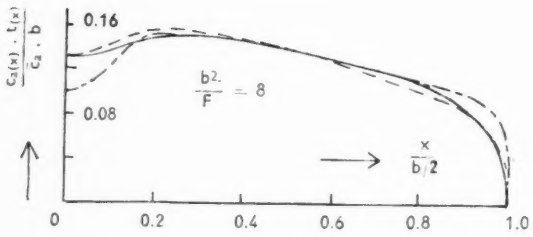


FIG. 7.

Comparison curves for a wing without twist with cut-out in centre. All three curves enclose equal area.

KEY FOR FIG. 7.

— · — · — *Chord distribution.*
——— *Approximation.*
– – – – *Exact by Multhopp's method.*

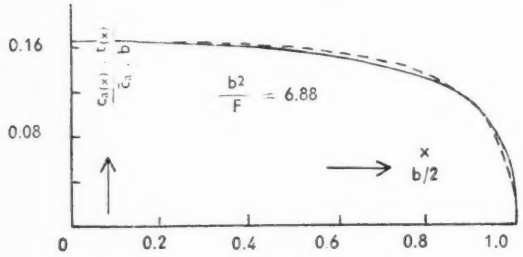


FIG. 8.

Comparison curves for a rectangular wing with semi-circular rounding, without twist. The deviation of the approximation method at the wing tip for the non-rounded rectangular wing here almost completely disappears.

KEY FOR FIGS. 8, 9, 10.

——— *Approximation.*
– – – – *Exact by Multhopp's method.*

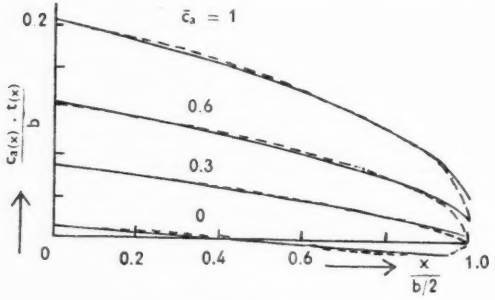


FIG. 9.

Comparison curves for a wing with t_a: t_1=0.5 and b^2/F=6.67 for various values of c_a with a linear twist which is 0° at the centre and 3° downwards at the wing tip.

Further refinement through additional computations, at the expense of briefness and simplicity, does not appear to be of advantage. The deviations, moreover, occur at such positions where the exact theoretical solution does not agree with actuality—for example, for unrounded wing tips and at transition positions of ailerons and flaps.

The deviations at the transition positions of ailerons and flaps can be readily balanced by hand with the aid of examples given in the figures.

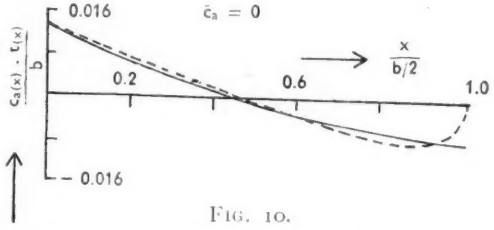


FIG. 10.

Larger scale representation of the curves for $c_a=0$ from Fig. 9.

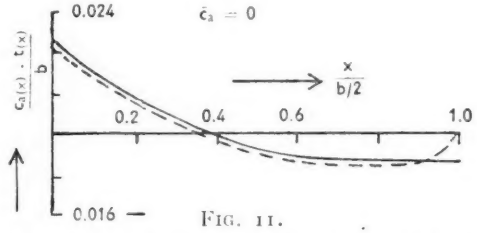


FIG. 11.

Results for $c_a=0$ as in Fig. 10 with a twist which similarly amounts to 3° at the wing tip but increases parabolically.

KEY FOR FIGS. 11, 12, 13.

——— *Approximation.*

– – – – *Exact by Multhopp's method.*

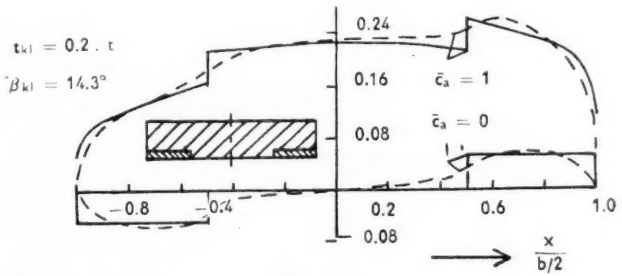


FIG. 12.

Comparison curves for a rectangular wing with $b^2/F=5$ for an aileron deflection $\beta=0.25 \approx 14°$ with and without lift. The corners of the approximation curve can practically be well rounded off by hand following the example given thus considerably better agreement is obtained. The rolling moments of the non-rounded off approximation curve very well agree with the exactly computed values.

POSSIBILITIES OF APPLICATION.

The method, as may be seen, is suitable for all problems where too great accuracy is not required; that is, in general, for investigations with regard to the maximum lift coefficient $c_{a\,max}$, stalling, and static equilibrium problems. By the decomposition into an ideal, plan form, and twist distribution, simple and time-saving relations may be set up for frequently repeated computations of bending moments, transverse forces, and torsional moments along the span. For the computation of the induced drag and for the downwash computation, the method is not directly applicable.

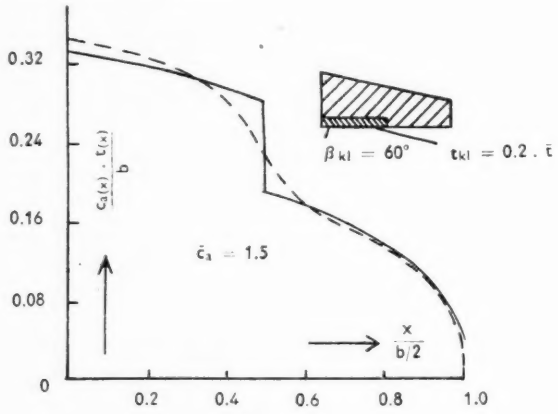


FIG. 13.

Comparison curves for a tapered wing with t_a: t_i=0.5 and b^2/F=6.67 with 60° deflected split flap along centre half of span.

The method is suitable for the determination of lift distributions also in cases for which the usual methods fail completely. Thus, it is applicable to monoplane wings with end plates. Ideal distributions that take the place of the ellipse can be computed on the basis of an investigation of the Aerodynamic Experimental Institute (reference 1)—the distributions there given for smallest induced drag and constant downwash. The relation for the lift distribution now becomes:—

$$\frac{dA}{dx} = \tfrac{1}{2}\, q\, \frac{dc_a}{d\alpha}\, \alpha t\,(x) + \bar{t}\, \frac{f\,(x)}{\frac{1}{b}\int_{-b/2}^{b/2} f\,(x)\, d\,(x)} + \tfrac{1}{2}\, q\, \frac{dc_a}{d\alpha_\infty}\, \delta\,(x)\, t\,(x)$$

where $f(x)$ is the function denoted by Mangler as the "ideal function" for the given case with end plates.

The method should likewise find application to biplanes and other arrangements.

SUMMARY.

The approximation method described makes possible lift-distribution computations in a few minutes. Comparison with an exact method shows satisfactory agreement. The method is of greater applicability than the exact method and includes also the important case of the wing with end plates.

REFERENCE.

1. Mangler, W. The Lift Distribution of Wings with End Plates. T.M. No. 856, N.A.C.A., 1938.

REVIEWS.

AIRCRAFT MATHEMATICS.

S. A. Walling and J. C. Hill, B.A. Cambridge University Press. 1941. 2/9.

This is one of the better books on elementary mathematics. Written primarily to supply a progressive course for Air Training Corps cadets, it will be found first class for anyone in aviation who wishes to brush up his elementary mathematical knowledge, or wishes to start *de novo*.

This is a book, entitled "Aircraft Mathematics," and it justifies its title. The great majority of the examples and exercises given have the proper aircraft setting. Nothing is more disheartening to an aircraft student than to work out example after example which are not particularised to the work he may have to do. In this book the authors have had in mind the application of all the mathematics in the book to aeronautics and aeronautics only. The field covered is from arithmetic to trigonometry, and covered so soundly that anyone who can work through any of the examples given will have a sound foundation on which to build for any of the examinations the R.A.F. may ultimately have in store for him.

"Aircraft Mathematics," indeed, starts the student in the right way, by making mathematics an interesting and practical subject. It is the right textbook, written in the right way, for the right people.

PRACTICAL FLYING IN WAR AND PEACE.

By Sqd. Com. A. H. Munday. Musson Book Co., Toronto. 1940. $3.00.

Squadron Commander Munday's career, as outlined on the jacket and in the foreword of the book, is sufficient guarantee of his competence to write it. His ambitious aim is to offer the air-minded layman "a complete course in practical flying." In 340 pages he deals with Navigation, Meteorology, Flying of all types, including Bombing, Engines and Instruments, Wireless, Materials, Construction and Maintenance of Aircraft, Aerial Photography, and various other aspects of aviation. It is astonishing that he should cover so much ground in so little space.

The student who reads this book will learn a great deal, though its ruthless simplification may sometimes leave him a trifle bewildered. For example, in an explanation of the triangles of velocities, we read that: "The wind is 50 m.p.h. from the S.E.," and are then told to "draw a line north-west *in the direction of the wind*"; the use of the phrase "down wind" would have averted a seeming contradiction that is likely to confuse the beginner. A compass course is defined as "the angle between the direction in which the compass points approximately north and the meridian on which a point lies." The author knows what he means, so do we—but does the reader? Again, in the definition of soft iron (p. 223), it might be pointed out that the term "soft" is used in the magnetic and not in the metallurgical sense.

There should be a great demand for this book, especially now that so many young English pilots are in Canada, and so many air-minded Canadian boys are waiting until they are old enough to join the R.A.F. It is in the certainty that further editions will soon be published that we venture to offer some suggestions: (1) The inclusion of a bibliography at the end of each chapter, so that the student may go more deeply into the subject if he wishes; (2) careful checking for spelling mistakes, such as "Air Vice Marshall," "Amy Mollinson," "McCrudden"—spelt twice right and twice wrong—and "Immelman," spelt wrong throughout. (3) Suppression of the irritatingly old-maidish italics used

for emphasis, as distinct from those which are quite properly used to introduce a new technical term or to call the student's attention to an important point.

THE MORSE CODE, LEARNING AND PRACTICE.

By R. G. Shackel. Longmans, Green. 1/-.

If you hear your neighbour in the bus chanting gaily: "*Dah* d' d' de, d' d' *dah* de," do not conclude he is an escaped lunatic; more probably he is carrying out Mr. Shackel's precept to practice his Morse aloud wherever he goes. Having learned Morse visually—with the resultant confusions, at any speed over twelve words a minute, of G and W, U and D, C, X and Y—the reviewer has cause to appreciate this innovation.

Other novel features of this splendid little book are the mixing of figures and letters, the block arrangement of exercises (enabling the teacher to confound pupils with a photographic memory, by dictating up and down or in reverse, or by shifting the code groups by a letter or two to the left or right), and the eminently practical nature of the plain-language sentences. These exercises are graded from two to twelve words per minute.

The circulation of this book, at a price which puts it within everyone's reach, ought to prove an accurate indication of the number of Morse students in this country, for any class which does not use it will be at a disadvantage.

SAFETY IN FLIGHT.

By Assen Jordanoff. Funk and Wagnalls. $3.00. (In England, 16/6.)

Some years ago we saw a film in which Lionel Barrymore, as an air line manager, kept striding up and down, muttering intensely: "The mail *must* go through!" Had he read the present book, more of his pilots might have been alive at the end of the story. Storm fronts, as viewed by the author, are neither a challenge to heroism nor a jigsaw puzzle of wind-arrows and contour lines to be worked out at leisure in an office, but rather the subject of a friendly conspiracy between pilot and meteorologist to cheat the Clerk of the Weather. He remarks pithily that: "It is a common fallacy for airmen to summarise present weather rather than to anticipate changes," and aims at developing this faculty of anticipation. He presents the reader with a series of unpleasant situations, admirably illustrated by diagrams, and asks: "What would *you* do, if . . . ?" Written for American readers, the book presupposes a Continental type of weather, varying over large land masses, rather than our own familiar climate, where the particular type of unpleasantness found at the starting-point is likely to prevail all along the route.

Approximately half the book is taken up with the practical application of meteorology; the remainder deals with instrument flying, radio beams, icing dangers and their counter-measures, engine efficiency under varying conditions, undercarriages, special landing and take-off conditions.

Assen Jordanoff has a gift for pictorial statement ("The day was so perfect that if the light rays could go around the earth, you would be able to see your own back." "I felt that I would not get out of this predicament—unless someone would move the mountain underneath out of my way before I reached it"), while his illustrator is a master of the pictorial diagram, which conveys far more to the average reader than a conventional graph would do. (The diagram on page 349 illustrating wing-lift during a turn is a case in point.)

Our only criticism of this admirable book is that the author seems undecided what degree of proficiency his readers possess. A man who can fly on instruments and interpret weather maps surely does not need to be told that: "The greater the load, the higher the stalling air speed of the plane will be prior to landing." The intercalated Tales with a Moral, entitled "The Things They Do," seem to be addressed to a certain exhibitionist type of club pilot. Jordanoff's "Flying Dodo" would undoubtedly have killed himself many times over, before reaching the point where this book would be of use to him.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES,

NOVEMBER, 1941.

Associate Fellowship Examinations.

The next Associate Fellowship Examinations will be held in the Offices of the Society on the mornings of December 9th, 10th, and 11th, 1941. The Library will be closed on those days. Full particulars will be sent to each candidate.

Air Training Corps.

6th October, 1941.

DEAR SIR,—The scheduled training of the Cadets of the Air Training Corps is taken care of by the officers of the Corps and civilian instructors, who work on a regular time table. This system is entirely satisfactory.

2. The gap, however, in the training of the units of the A.T.C. is the lack of direct aviation interest, except when the Cadets are able to visit R.A.F. aerodromes.

3. There must be a number of your members who, while unable to give standard instruction at definite times to Cadet units, would be glad to give occasional talks on any phase of aviation suitable for these young men. Aviation interest of this kind is an immense stimulus to the Cadets, and I should be grateful if you could find means of bringing our needs to the notice of your members.

4. The work would be so arranged as to be in the neighbourhood of the speaker's home, so that travelling and expenditure might be kept to a minimum.

5. I should be glad to hear from any of your members who are willing to give interest talks of this kind (and I cannot think that anyone who has been connected with aviation in any capacity has not a great fund of stories at his disposal), so that I may put them in touch with units conveniently situated.

Yours faithfully,

B. ROCKEY, *S./Ldr.*,
for J. A. CHAMIER, *Air Commodore*,
Commandant, Air Training Corps.

The Secretary,
The Royal Aeronautical Society,
4, Hamilton Place, London, W.1.

Acknowledgments.

The Council acknowledge with grateful thanks the following gifts to the Library:—

Mr. Griffith Brewer: Photographs of Wright Field Museum; photostats of letters from Orville Wright (1903) and other interesting data regarding the original Wright aeroplanes.

Discussions.

In accordance with the notice which appeared in the JOURNALS for July, August and September, 1941, the following discussions have already been held:—

1. The Future of British Civil Aviation.
2. Drag Reduction.
3. Application and Correlation of Wind Tunnel and Full-Scale Testing.

Further discussions are being arranged, provided a sufficient number of members indicate their wish to attend, on:—

4. Drawing Office Methods.
5. Vibration Problems.
6. Tolerances, Limits and Inspection.
7. Control Surface Design.

Members are reminded that they will not receive an intimation of the date and place of any of the discussions unless they write in to the Secretary and indicate their desire to attend.

Amy Johnson Memorial Fund.

The following donation has been received:—

Mr. A. J. Hughes, Fellow ... ... £1 1s. 0d.

Election of Members.

Fellow.—George William Williamson (from Associate Fellow).

Associate Fellows.—Edmund Turney Allen, Edgar Hilton Atkin, Maurice Luby, Fred Rowarth.

Associates.—James Warner Bird, Sydney Richardson Cauthery, James Daly, John Jerome Dillon, Philip Burns Dumbell, William Sidney James Grant (from Student), Sidney Alexander Metcalf, John Logan Topping.

Graduates.—Frank William Crowhurst, Yehuda Holbitz, Brian Robert Munn Hunter-Steen, Stanley Gordon Marshall, Peter Ralph Price, Norman Purssell, Alexander Zielony (from Student).

Companion.—John Thomas Blundell.

Students.—Peter Kenneth Brack, Thomas Barrie Bryant, Peter Alan Coles, Alan Edgar Crawford, Peter John Detmold, Ewart Joseph Dyke, Raymond Hart, Philip George Kendrick, Roy Hume Long, Richard Arthur McGill, Frederick John Milligan, Douglas Burton Morrell, Harold Clifford Olding, Peter Person, Ronald Ernest Phillips, Elisabeth Constance Pike, Douglas Charles Ramsay, George Hinson Rider, Peter Edward Saunders, Douglas Norman Scard, Duncan John Stewart, Alfred Stanley Taylor, Leonard Teff, John Henry Walmsley, Marjorie Doris Watkins, Murry Pearce White.

Lecture at the Institution of Mechanical Engineers.

The attention of members of the Society is drawn to a lecture on "The Axial Vibration of Diesel Engine Crankshafts," to be read by Mr. Ralph Poole, Associate Fellow, before the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, at 2.30 p.m., on Friday, December 19th, 1941. Members of the Society are invited to attend this lecture.

Advertisements.

The fact that goods made of raw materials in short supply, owing to war conditions, are advertised in the JOURNAL should not be taken as an indication that they are necessarily available for export.

Additions to Library.

Pamphlets in italics, with location reference following in brackets.
Books marked * or ** are not available for loan.

A.a.292 and 293.—First Principles of Flight. D. Hay Surgeoner. Longmans, Green and Co. 1941. 3/6. (Two copies.)

B.a.249.—Flying Fleets. S. Paul Johnston. Duell, Sloan and Pearce, New York. 1941. $3.

BB.b.91.—*The Proportioning of Aircraft Frameworks. N. J. Hoff. (Reprint from "Journal of Aeronautical Sciences," June, 1941.)* (Y.8.a.20.)

D.b.164 and 165.—*Ocean Air Transport. J. T. Trippe. (Reprint from "Intava World," August, 1941, of Wilbur Wright Memorial Lecture, abridged.) Pan American Airways.* 1941. (Y.6.a.28 and 29.) (Two copies.

D.c.86.—*Airport Construction. Series of articles in "Highways and Bridges," Aug. 6-Oct. 1, 1941.* (Y.4.ii.a.29.)

J.b.13.—*India Meteorological Department, Scientific Notes, Vol. VIII.*

No. 92. Correlation between Frost and the preceding Meteorological Conditions. II (Jaipur). Barkat Ali and S. N. Naqui. 1941. 6d.

No. 93. Heat Radiation from the Atmosphere at Bombay and its Comparison with that at Poona. R. Narayanaswami. 1941. 10d.

L.d.67.—Simplified Aerial Navigation. (2nd Ed.) J. A. McMullen. Chas. Griffin and Co. 1940. 5/-.

S.a.122.—Fighting Planes and Aces. W. E. Johns. John Hamilton. 1932. 5/-.

S.e.30.—Rule Britannia. Cecil King. Studio Publications. 1941. 12/6.

*S.e.31.—Bomber Command. Ministry of Information. H.M.S.O. 1941. 1/6.

*V.1/21.—Sixty-Year Index, A.S.M.E. Technical Papers, 1880-1939. American Society of Mechanical Engineers. 1941.

Correction.

In the paper "A Note on the Limitations of Aircraft and Aerofoils Used for High Flying Aircraft," by J. A. C. Williams, published in the October Journal, the following should be inserted on page 325, line 9, after "high performance aircraft":—

"Equation (1) holds for the case of straight level flight but not for the case of accelerated flight. In this latter case, which is of special importance in fighter aircraft, the actual wing loading will be increased by the acceleration factor."

J. Laurence Pritchard, *Secretary and Editor.*

THE MECHANICAL IMPEDANCE OF DAMPED VIBRATING SYSTEMS.

By R. G. Manley.*

I. Introduction.

The concept of "mechanical impedance," a quantity equivalent to Biot's Dynamic Modulus (reference 1), has been utilised since 1939 by the de Havilland Aircraft Company as a standard method of treatment of vibration problems in engine airscrew systems, the method being applied principally to torsional vibrations. In this work the effect of damping forces was neglected, on the assumption that the resonant frequencies of a system are not affected appreciably by such forces so long as they remain of small magnitude.

The desire to justify this assumption by theoretical reasoning, and to evolve a method of attack for problems in which the damping forces are too large to be neglected, led to the application of the concept of mechanical impedance to damped systems.

II. Summary.

The quantity "mechanical impedance" is defined for linear mass-spring systems, for simplicity; the corresponding quantity for torsional motion can easily be derived. A general method for determining the resonant frequencies of damped linear systems is developed, and it is shown that if the damping forces are small they do not affect the resonant frequencies.

III. Analysis.

1. Undamped Systems.

At a point P in an undamped linear vibrating system a force $f=F \cdot \sin \omega t$ is applied; the resulting displacement at P in steady state vibration is $x=X \cdot \sin \omega t$. The ratio $f/x=F/X$ is defined as the mechanical impedance of the system at P, and is denoted by Zp.

Two formulæ for the transference of the reference point P are very useful.

(i) Transference through a mass (Fig. 1). The impedances of the system to the right of the points A, B are Z_A, Z_B; using suffixes similar to denote the reference points for forces and displacements,

$$x_B=x_A=x$$
$$f_B=f_A+m\ddot{x}$$

For sinusoidal motion $x=X \cdot \sin \omega t$, $\ddot{x}=-\omega^2 x$; hence

$$f_B=f_A-m\omega^2 x.$$

The impedance relation follows:—

$$Z_B=Z_A-m\omega^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

(ii) Transference through a spring (Fig. 2). With the same notation,

$$f_B=f_A=f$$

and

$$x_B=x_A+f/k$$

hence

$$x_B/f_B=x_A/f_A+1/k$$

or

$$1/Z_B=1/Z_A+1/k \quad . \quad . \quad . \quad . \quad . \quad (2)$$

* (Of the de Havilland Aircraft Company, Ltd.)

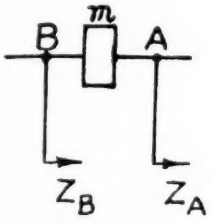
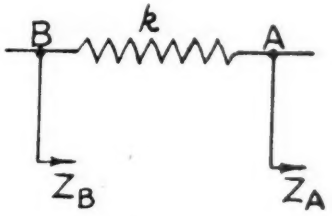


FIG:1



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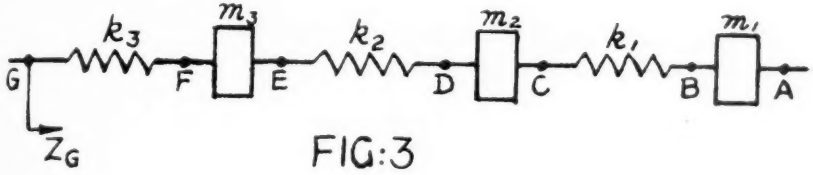

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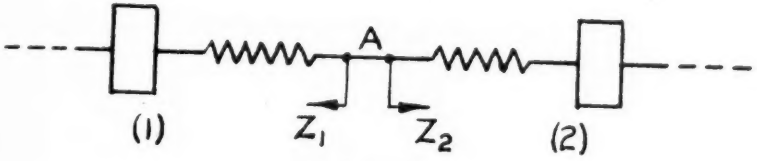


FIG:4

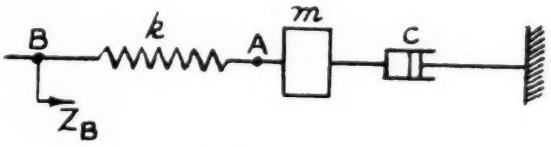
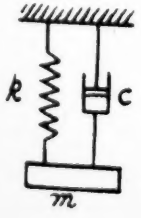


FIG:5



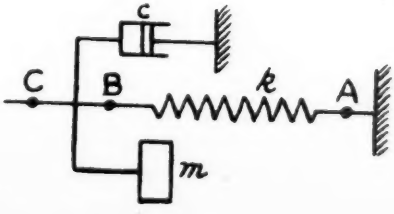
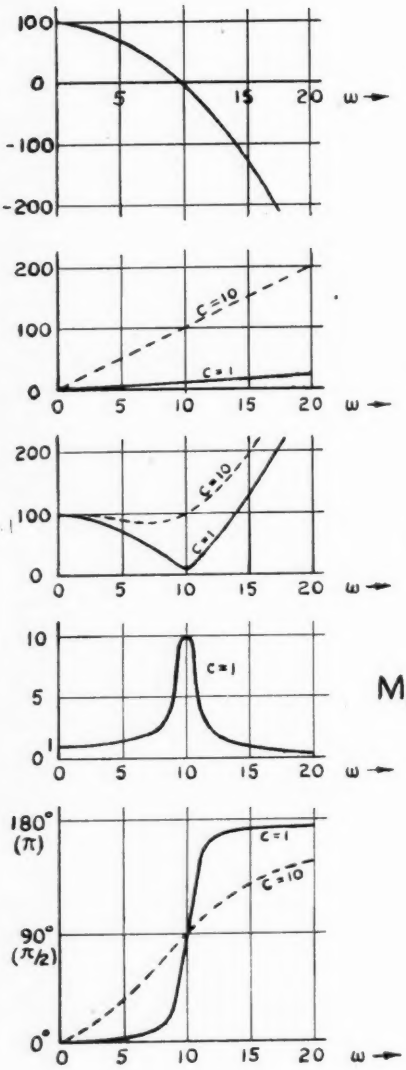


FIG:6



α IN-PHASE IMPEDANCE.
β π/2-PHASED IMPEDANCE.
|z| MODULUS OF IMPEDANCE.
M DYNAMIC MAGNIFIER.
φ PHASE ANGLE.

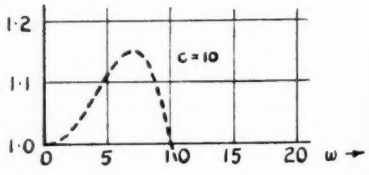


FIG: 7

Applying these equations to a system such as that of Fig. 3,

$$Z_A = 0$$
$$Z_B = Z_A - m\omega^2 = -m\omega^2$$
$$1/Z_C = 1/Z_B + 1/k,$$
$$Z_D = Z_C - m_2\omega^2, \text{ etc., etc.}$$

In this manner the impedance of the whole system at the point G is easily calculated if the numerical values of the masses and spring stiffnesses are given.

2. Resonance in Undamped Systems.

If two systems 1 and 2 are coupled at the point A (Fig. 4) the resonant frequencies are determined by the condition

$$(Z_A)_1 + (Z_A)_2 = 0 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

for the resonance condition is that the total input force at A is zero; hence (dropping the suffix A for convenience) $f_1 = f_2$. Moreover, there is the geometrical condition $x_1 = -x_2$, thus $f_1/x_1 = -f_2/x_2$, *i.e.*, $Z_1 + Z_2 = 0$.

This result is of great practical importance, as it enables the resonant frequencies of coupled systems to be determined if the impedance curves, as functions of the frequency $\omega/2\pi$, are known for the two parts of the system. If curves of Z_1 and $-Z_2$ are plotted on the same axes and to the same scale, the intersections determine the resonant frequencies of the combined system.

3. Inclusion of Damping.

The concept of impedance can now be extended to include viscous damping. An elementary linear system is depicted in Fig. 5. The dashpot exerts a force $c\dot{x}_A$ proportional to the velocity $\dot{x}_A$ of the mass. The total force f_A is then given by $f_A = m\ddot{x}_A + c\dot{x}_A$, which for sinusoidal motion ($x = X \cdot \sin \omega t$) becomes:—

$$f_A = -m\omega^2 X \cdot \sin \omega t + c\omega X \cdot \cos \omega t.$$

In vector notation this can be written $f_A = -m\omega^2 x + jc\omega x$, where j is the versor operator turning the associated vector through an angle $\pi/2$ in the positive sense. This complex number form is a more convenient one than that involving sine and cosine components, but care must be taken not to associate the usual notions of *real* and *imaginary* quantities with the complex force. The j part ($jc\omega x$) is a force phased $\pi/2$ ahead of the displacement and is just as *real*, physically, as the in-phase part ($-m\omega^2 x$).

The impedance z_A is then given by $z_A = -m\omega^2 + jc\omega$, and it is convenient to write this in the form:—

$$z_A = \alpha_A + j\beta_A, \text{ where } \alpha_A = -m\omega^2 \text{ and } \beta_A = c\omega.$$

The impedance z_B at B is given, as in equation (2), by $1/z_B = 1/z_A + 1/k$ and algebraic reduction gives the result:—

$$z_B = \alpha_B + j\beta_B$$

where

$$\alpha_B = k\left(1 - \frac{k\,(k+\alpha_A)}{(k+\alpha_A)^2 + \beta_A{}^2}\right) \quad . \quad . \quad . \quad . \quad (4)$$

and

$$\beta_B = \frac{k^2\beta_A}{(k+\alpha_A)^2 + \beta_A{}^2}$$

These results, although complicated in symbols, are easy to apply to numerical examples.

4. Resonance in Damped Systems.

With dissipation of energy via damping, steady state oscillations can only occur if there is an input force. Suppose this force to be f_P applied at P, the

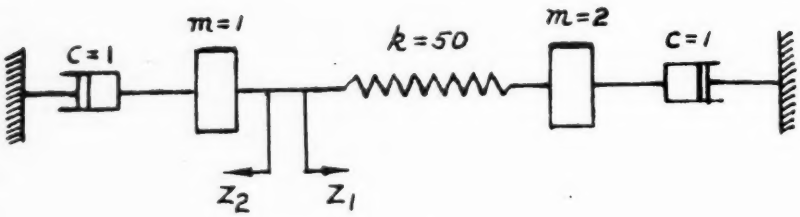

m=1
k=50
m=2
c=1
c=1
z_2
z_1

FIG: 8

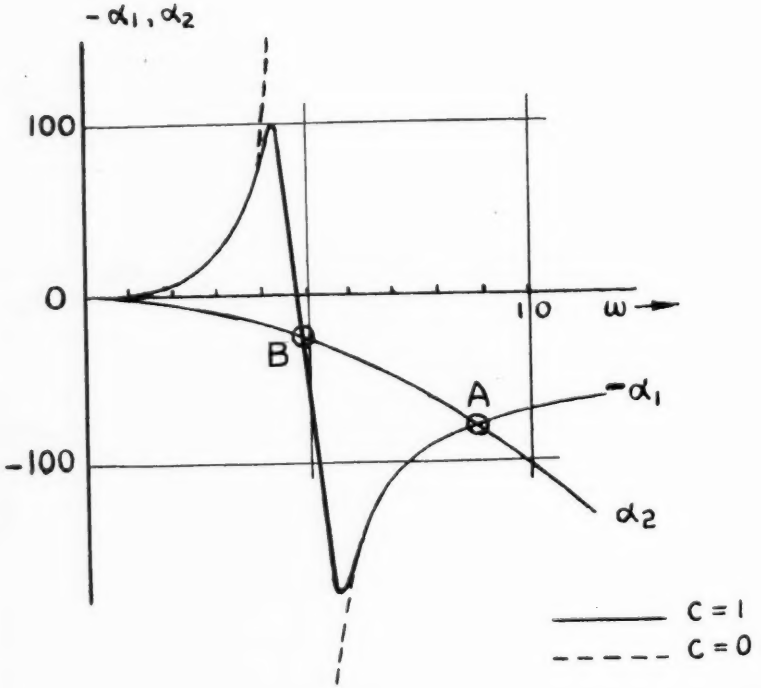

$-\alpha_1, \alpha_2$
100
0
-100
10
ω
B
A
$-\alpha_1$
α_2
c = 1
c = 0

FIG: 9

displacement at P being $x_P = X \cdot \sin \omega t$. Then

$$f_P = z_P x_P = \alpha_P x_P + j\beta_P x_P$$

The term $\alpha_P x_P$ is a force in phase with the displacement, while the term $j\beta_P x_P$ is a force phased $\pi/2$ ahead of the displacement. Practically, resonance is the condition of maximum displacement amplitude X for a constant exciting force, which corresponds to a minimum magnitude of the modulus of impedance defined as $|z| = +\sqrt{(\alpha^2 + \beta^2)}$. If the damping forces are small, this condition occurs when in-phase force $\alpha_P x_P$ is zero (reference 2), so that the resultant force is equal to the j part and is phased $\pi/2$ ahead of the displacement. If the damping forces are large, the frequency at which the displacement amplitude is a maximum, is not the same as that at which the phase angle is $\pi/2$, as will be shown in the next section.

5. Illustrative Example.

Consider the simple system shown in Fig. 6, the right hand part of which illustrates a more convenient way of laying out the diagram than the conventional left hand part. The impedances at A, B and C are: $z_A = \infty$; $z_B = k$: $z_C = k - m\omega^2 + jc\omega$; thus

$$\alpha_C = k - m\omega^2, \quad \beta_C = c\omega, \quad |z|_C = +\sqrt{(\alpha_C^2 + \beta_C^2)},$$

and the angle ϕ_C at which the force at C is phased ahead of the displacement at C is given by: $\tan \phi_C = \beta_C/\alpha_C$. One further quantity can usefully be defined in terms of impedance: the Dynamic Magnifier

$$M = \frac{\text{dynamic displacement due to force } F \cdot \sin \omega t}{\text{static displacement } (\omega = 0)}$$

For a given force F_C, the displacement X_C is $\dfrac{F_C}{|z|_C}$

where capital letters denote maximum values. Then

$$M_C = \frac{X_C}{(X_C)_{\omega=0}} = \frac{(|Z|_C)_{\omega=0}}{|Z|_C}$$

Curves of α_C, β_C, $|z|_C$, M_C and ϕ_C are plotted against ω in Fig. 7. The numerical values of the dynamic constants are $m = 1$, $k = 100$, $C = 1$ (full curves) and $C = 10$ (dotted curves). From these diagrams it is clear that for $C = 1$ (*i.e.*, 1/20th of the critical value) the practical resonance coincides with the theoretical resonance ($\phi = \pi/2$) at $\omega = 10$, but for $C = 10$ (i.e., 1/2 critical value) the practical resonance occurs at $\omega = 7$ approximately. The amplitudes of vibration in the two cases are very different and attention is drawn to the scales of the two curves of the dynamic magnifier M_C.

6. Resonances of Multi-Mass Systems.

If the damping forces are small, the resonant frequencies of a coupled system, consisting of two systems 1, 2 joined and forced at P, are given, by virtue of the definition of resonance, by the equation $\alpha_1 + \alpha_2 = 0$ (*cf.*, equation (3) for undamped systems). Hence the resonances can be determined by a procedure similar to that outlined in section 2 above, using curves of the in-phase impedance α_1, α_2. There is, however, one point of importance to be noted. Suppose the coupled systems are the simple linear ones shown in Fig. 8, the intersecting curves being drawn in Fig. 9; the dotted lines in this figure are the impedance curve for system (1) for zero damping, and it is evident that for zero damping there is one resonance (A) while for finite damping there appear to be two resonances (A) and (B). This conclusion is not borne out by practical results. Ordinary methods of analysis applied to the system of Fig. 8 show that the "resonance" marked B in Fig. 9 does not correspond to a condition of maximum displacement amplitude of the system for a given input force, as does the resonance A. Now, this condition of maximum displacement amplitude con-

stitutes the *practical* condition of resonance, for in this state the system responds to a given force by vibrating at large amplitudes. Thus the " resonance " B, although it conforms to the condition $\alpha_1+\alpha_2=0$, does not constitute what an engineer regards as a practical resonance.

Further investigation has shown that this result holds in general and that no particular physical condition is determined by such intersections.

We therefore term such resonances " spurious," and disregard any intersections occurring at such parts of the curve as correspond to the discontinuities in the curves for zero damping.

Numerical investigation shows that for small damping forces the in-phase impedance curve is very nearly identical with the impedance curve zero damping, except at parts of the curve which correspond to discontinuities in the case of zero damping (see Fig. 9). Since the intersections on these latter parts of the curve are regarded as not indicating true resonances, it follows that for small values of the damping coefficients the effect of damping forces on the resonances of systems is negligible.

If the damping forces are large, the resonances can be found from the condition that at resonance the modulus of the total impedance is a minimum, *i.e.*, the displacement amplitude is a maximum for a given input force. (The total in-phase impedance is the sum of the individual in-phase impedances at the coupling point, and similarly for the j part. The modulus of the total impedance is found in the usual manner from these two quantities.) This procedure is quite simple to follow in numerical work.

Note on Torsional Vibrations.

All the above analysis applies equally to the case of torsional vibrations, the change from the linear units to the torsional units being effected by putting polar inertia, torque, angular displacement and stiffness in the place of mass, force, linear displacement and stiffness. With these substitutions all the formulæ and the results are applicable to torsional systems.

IV. Conclusions.

The foregoing analysis shows clearly that the effect of small damping forces can be neglected in the calculation of the resonant frequencies of vibrating systems. In practice this allows the continued use of the impedance curves calculated on the assumption of zero damping. Furthermore, if the damping forces are large, the methods described enable the vibration characteristics of the system to be determined with an ease hitherto regarded as unattainable.

The author wishes to acknowledge the assistance of Mr. J. W. Head, who performed much of the numerical work from which these conclusions have been drawn.

References.

1. Biot, M. A. " Coupled Oscillations of Aircraft Engine—Propeller Systems." Journal of Aeronautical Sciences, Vol. 7, No. 9, July, 1940.
2. Den Hartog. " Mechanical Vibrations," 2nd Edition, Chapter II.

CALCULATION OF THE STRESSES IN ANNULAR FRAMES.*

By H. FAHLBUSCH and W. WEGNER.

(*Luftfahrtforschung, Vol.* 18, *No.* 4, *22nd April*, 1941, *pp.* 122 *to* 127.)

Translated by M. FLINT.

The stresses in annular frames of constant flexural stiffness, as they occur in thin-walled shells are determined, assuming a finite depth of frame cross-section. The calculations are carried out for the fundamental load cases and the results presented in the form of diagrams.

CONTENTS.

I. Notations.

II. Equilibrium of the frame.

III. Determination of the stresses in circular frames of constant flexural stiffness, loaded in their plane by :—

Load Case A. A radial force applied locally.

Load Case B. A moment locally applied in the axis of gravity of the frame.

Load Case C. A tangential force applied locally at a distance r.

Load Case D. A tangential force applied locally at a distance R.

IV. Numerical example.

V. Range of validity.

I. NOTATIONS.

P = force.
s = thickness of metal sheet.
S = static moment.
I = moment of inertia.
EI = flexural stiffness.
τs = shear flux.
ϕ_0 = variable angle at the centre.
ϕ = angle at the centre.
r = distance of the neutral fibres from the centre of the circle.
R = distance of the shear flux from the centre of the circle.
e = distance of the shear flux from the neutral fibres.
x = distance centre of shear from the centre of the circle.
M = moment.
B = bending moment.
N = normal force.
Q = transverse force.
X = statically indeterminate.
δ = load or load coefficient.

* R.T.P. Translation No. 1218. Published by permission of the Ministry of Aircraft Production.

II. Equilibrium of the Frame.

Annular frames are provided for the transmission of transverse forces into a circular shell with large R/s ratio. They are in equilibrium with the single loads and the shear forces from the shell. Every load can be resolved into the transverse force passing through the elastic c.g. of the shell and the moment, Fig. 1.

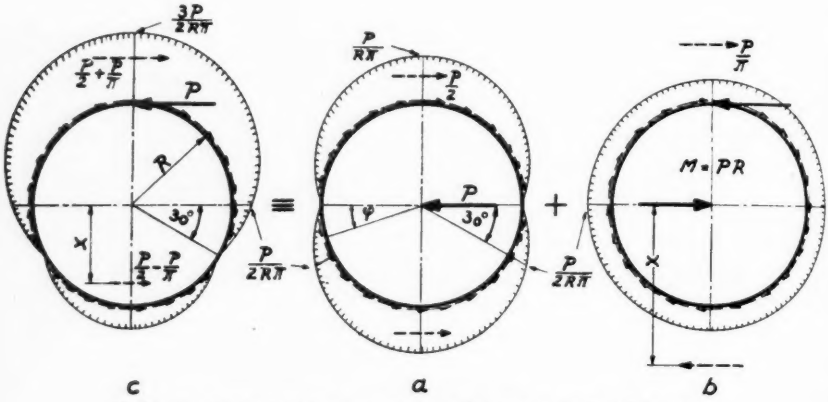


Bild 1. Das Gleichgewicht des Spantes und die Zerlegung in die Grundbelastungen.

Fig. 1.

The equilibrium of the frame and analysis into the fundamental loads.

The transverse force, as a result of bending under shear gives rise to a sinusoidal shear flux in the shell, which extends as far as the frame, Fig. 1*a*:—

$$\tau s = \frac{P}{I} S$$

If the moment of inertia of the circular shell is

$$I = \pi R^3 s,$$

the function

$$\tau s = \frac{P}{\pi R} \sin \phi$$

represents the distribution of the shear flux.

The distance of the centre of shear of a half circle for a sinusoidal distribution from the centre of the circle is:—

$$x = \frac{R \int_0^{\pi} \tau s \, d\alpha}{P/2} = \frac{4}{\pi} R \approx 1.27 R.$$

The shear flux acting on the frame due to a moment is constant and is of the value, Fig. 1*b*,

$$\tau s = \frac{M}{2 R^2 \pi}$$

The distance of the centre of shear of a half circle for a constant distribution from the centre of the circle is

$$x = \frac{\pi}{2} R \approx 1.57 R.$$

The resultant shear flux is given by the equation, Fig. 1c,

$$\tau s = \frac{P}{R\pi}\sin\phi + \frac{M}{2R^2\pi}$$

The distance of the centre of shear of a half circle from the centre of the circle on one side is

$$x = \frac{4+\pi}{\pi+2}R$$

and on the other side

$$x = \frac{4-\pi}{\pi-2}R$$

III. Determination of the Stresses of Annular Frames of Constant Flexural Stiffness.

Load Case A.

Load Due to a Force Applied Locally in the Radial Direction.

In general the annular frame is threefold statically indeterminate, in the present case however, and also in the subsequent load cases the calculation can be considerably simplified by judicious selection of the section boundaries. At the position o with the load represented in Fig. 2, the statically indeterminate $X_3 = 0$. The signs to be used for the calculation are determined as shown in Fig. 4. The depth of the frame cross-section is introduced into the calculation by the ratio r/R. The results hold for $r/R \lessgtr 1$, Fig. 3.

Bild 2. Lastfall A. Radialbelastung.

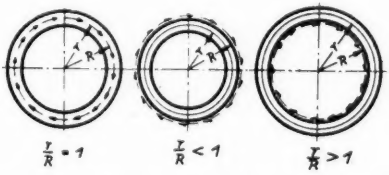


Bild 3. Darstellung des Verhältnisses $\frac{r}{R}$ bei gleichem Schalendurchmesser

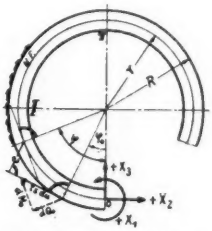


Bild 4. Bestimmung von B_o, N_o und Q_o und Vorzeichenfestlegung.

FIG. 2.

Load Case A. Radial load.

FIG. 3.

Representation of the ratio r/R with the same shell diameter.

FIG. 4.

Determination of B_o, N_o and Q_o and establishment of sign.

The equations of elasticity are:—

$$\delta_{1o} + X_1\delta_{11} + X_2\delta_{12} = 0,$$
$$\delta_{2o} + X_1\delta_{21} + X_2\delta_{22} = 0.$$

The displacement quantities are generally determined as:—

$$EI\delta_{ik} = \int B_i B_k du.$$

Determination of the distribution of the bending moment in the statically determinate principal system, relative to the neutral fibres, is shown in Fig. 4.

The element of shear acting tangentially

$$\tau s du = \tau s R d\phi_0$$

produces in the frame ring at the position ϕ the bending moment

$$dB_0 = -\tau s du e.$$

The distance e is given by the following geometrical relation :—

$$e = R - r(\sin\phi_0 \sin\phi + \cos\phi_0 \cos\phi).$$

The bending moment B_0 at the position ϕ is then :—

$$B_0 = -\frac{PR}{\pi}\int_0^{\phi} \sin\phi_0 d\phi_0 + \frac{Pr}{\pi}\sin\phi \int_0^{\phi} \sin^2\phi_0 \, d\phi_0 + \frac{Pr}{\pi}\cos\phi \int_0^{\phi} \sin\phi_0 \cos\phi_0 d\phi_0,$$

hence :—

$$B_0 = \frac{P}{\pi}(R\cos\phi + r\frac{\phi}{2}\sin\phi - R).$$

Further,

Since $X_1 = 1$, $B_1 = 1$.

Since $X_2 = 1$, $B_2 = r(1 - \cos\phi)$.

For reasons of symmetry, integration is necessary over one half ring only. The following loads and load coefficients are obtained :—

$$EI\,\delta_{10} = \int_0^{\pi} B_1 B_0 du = Pr\left(\frac{r}{2} - R\right),$$

$$EI\,\delta_{20} = Pr^2 R\left(\frac{5}{8}\frac{r}{R} - \frac{3}{2}\right),$$

$$EI\,\delta_{11} = r\pi,$$

$$EI\,\delta_{22} = \frac{3}{2}r^3\pi,$$

$$EI\,\delta_{12} = EI\,\delta_{21} = r^2\pi.$$

By solving the equations of elasticity we obtain the value of the statically indeterminates :—

$$X_1 = -\frac{Pr}{4\pi}, \quad X_2 = \frac{P}{\pi}\left(\frac{R}{r} - \frac{1}{4}\right).$$

The final distribution of the bending moment is then :—

$$B = B_0 + X_1 B_1 + X_2 B_2,$$

$$\boxed{B = \frac{Pr}{2\pi}(\phi\sin\phi + \tfrac{1}{2}\cos\phi - 1)} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The final distribution of the normal force is determined from the equation :—

$$N = N_0 + X_1 N_1 + X_2 N_2.$$

The normal force N_0 in the statically determinate principal system at the position ϕ is obtained by resolution of the shear force element into the tangential component and integration from 0 to ϕ, Fig. 4.

$$dN_0 = -\tau s du \cos(\phi - \phi_0),$$

$$N_0 = -\frac{P}{2\pi}\phi\sin\phi.$$

The distribution of the normal force in the statically indeterminate system is then calculated and found to be :—

$$\boxed{N = \frac{P}{2\pi}\left(\frac{2}{r}R\cos\phi - \tfrac{1}{2}\cos\phi - \sin\phi\right)} \quad . \quad . \quad . \quad . \quad (2)$$

Similarly we obtain the distribution of the transverse force:—

$$Q = \frac{P}{2\pi}\left(\phi \cos \phi + \frac{2R}{r}\sin \phi - \frac{3}{2}\sin \phi\right) \quad . \quad . \quad . \quad (3)$$

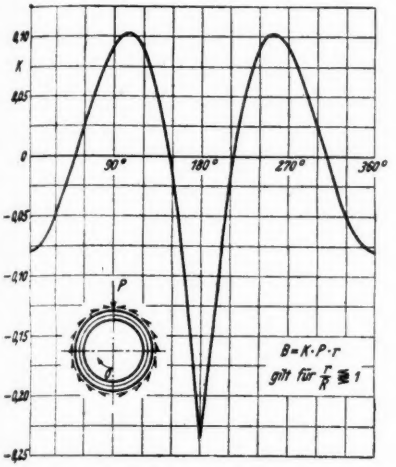


Bild 5. Biegemomente bei Radialbelastung.

FIG. 5.

Bending moment with radial load gilt fur $r/R \gtreqless 1$ = holds for $r/R \gtreqless 1$.

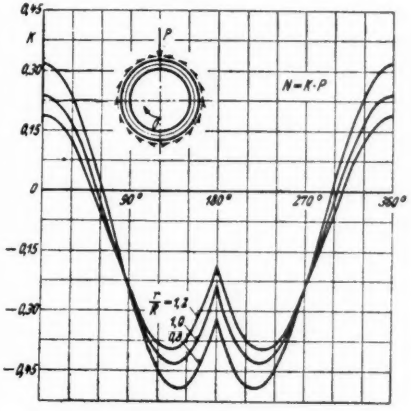


Bild 6. Normalkräfte bei Radialbelastung.

FIG. 6.

Normal forces with radial load.

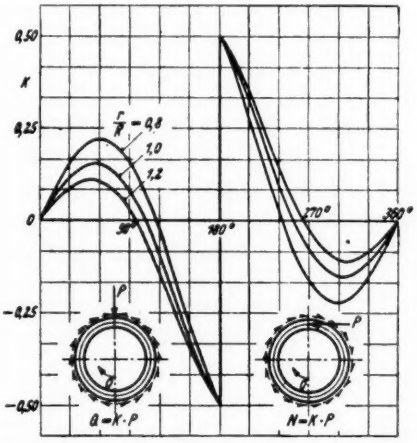


Bild 7. Querkräfte bei Radialbelastung, gleichzeitig Normalkräfte bei Tangentialbelastung (Abstand r).

FIG. 7.

Transverse forces with radial load, also normal forces with tangential load (distance r).

In Figs. 5 to 7 the distributions of the bending moment, normal force and transverse force are plotted over the circumference of the frame. The ratio r/R is introduced as parameter, namely, for $r/R = 1,\ 1.2,\ 0.8$.

Load Case B.

Load Due to a Moment Induced Locally in the Axis of Gravity of the Frame.

For this load the frame ring is simply statically indeterminate at the position o. The statically indeterminates X_1 and X_2 are equal to zero. The equation of elasticity is :—

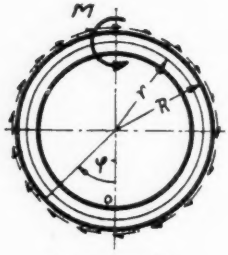
$$\delta_{30} + X_3 \delta_{33} = 0.$$

The distributions of the bending moment, normal force and transverse force in the statically determinate principal system are determined in the same manner as in load Case A.

$$B_0 = \frac{M}{2\pi}\left(\frac{r}{R}\sin\phi - \phi\right),$$

$$N_0 = \frac{M}{2R\pi}\sin\phi,$$

$$Q_0 = \frac{M}{2R\pi}(\cos\phi - 1).$$



$$B_0 = \frac{M}{2\pi}\left(\frac{r}{R}\sin\varphi - \varphi\right).$$

$$N_0 = -\frac{M}{2R\pi}\sin\varphi,$$

$$Q_0 = \frac{M}{2R\pi}(\cos\varphi - 1).$$

Bild 8. Lastfall B
Momentenbelastung

Fig. 8.

Load Case B. Moment load.

The load and load coefficients are of the following value :—

$$EI\,\delta_{30} = Mr^2\left(\frac{r}{4R} - \frac{1}{2}\right),$$

$$EI\,\delta_{33} = \frac{\pi}{2}r^3.$$

The statically indeterminate is calculated as :—

$$X_3 = \frac{M}{2r\pi}\left(2 - \frac{r}{R}\right).$$

The final distributions of the bending moment, normal force and transverse force acquire the values

$$B = \frac{M}{\pi}\left(\sin\phi - \frac{\phi}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$N = -\frac{M}{r\pi}\sin\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$Q = \frac{M}{r\pi}\left(\cos\phi - \frac{1}{2}\frac{r}{R}\right) \quad . \quad . \quad . \quad . \quad . \quad (6)$$

represented in Figs. 9 to 11.

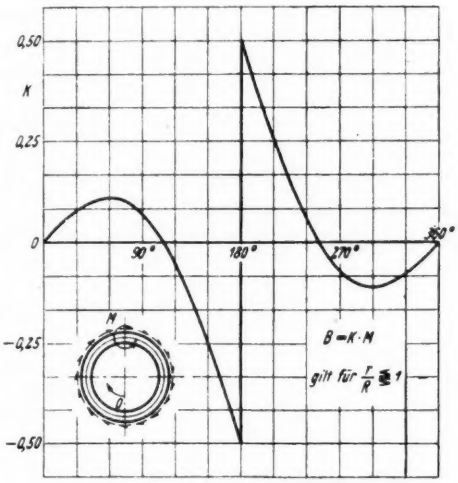


Bild 9 Biegemomente bei Momentenbelastung

FIG. 9.

Bending moment with moment load.

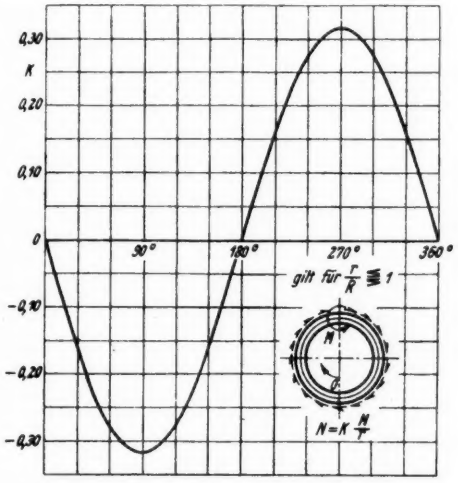


Bild 10. Normalkräfte bei Momentenbelastung.

FIG. 10.

Normal forces with moment load.

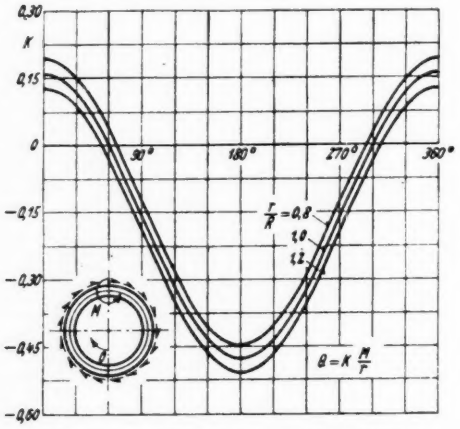


Bild 11. Querkräfte bei Momentenbelastung.

FIG. 11.

Transverse forces with moment load.

LOAD CASE C.

LOAD DUE TO A FORCE IN THE TANGENTIAL DIRECTION APPLIED LOCALLY AT THE DISTANCE r OF THE FRAME, FIG. 12.

For this load also the frame ring is simply statically indeterminate at the position o. The procedure for the calculation is similar to that followed in the foregoing load cases. The intermediate and end results are:—

$$B_o = \frac{Pr}{2\pi}\left(\frac{2R}{r}\sin\phi - \phi\cos\phi - \sin\phi + \frac{r}{R}\sin\phi - \phi\right),$$

$$N_o = \qquad \phi\cos\phi + \sin\phi - \frac{r}{R}\sin\phi\Big),$$

$$Q_o = \frac{P}{2\pi}\left(\phi\sin\phi + \frac{r}{R}\cos\phi - \frac{r}{R}\right);$$

further:—

$$EI\,\delta_{30} = \frac{Pr^3}{2}\left(\frac{R}{r} + \frac{r}{2R} - \frac{5}{4}\right),$$

$$EI\,\delta_{33} = \frac{\pi}{2}r^3.$$

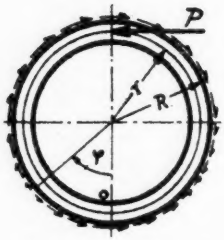


Bild 12. Lastfall C. Tangentialbelastung (Abstand r).

FIG. 12.

Load Case C. Tangential load (distance r).

and

$$X_3 = -\frac{P}{\pi}\left(\frac{R}{r} + \frac{r}{2R} - \frac{5}{4}\right).$$

$$\boxed{B = \frac{Pr}{2\pi}\left(\frac{3}{2}\sin\phi - \phi\cos\phi - \phi\right)} \quad . \quad . \quad . \quad . \quad (7)$$

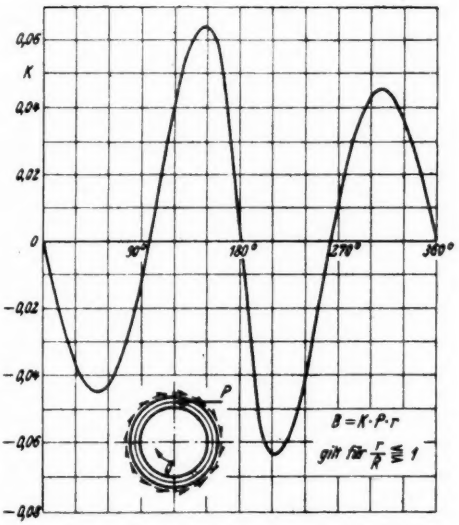


Bild 13. Biegemomente bei Tangentialbelastung (Abstand r).

FIG. 13.

Bending moment with tangential load (distance r).

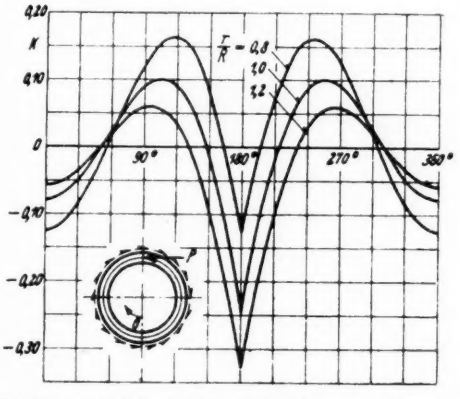


Bild 14. Querkräfte bei Tangentialbelastung (Abstand r).

FIG. 14.

Transverse forces with tangential load (distance r).

$$N = \frac{P}{2\pi}\left(\phi\cos\phi + \frac{2R}{r}\sin\phi - \frac{3}{2}\sin\phi\right) \quad . \quad . \quad . \quad (8)$$

$$Q = \frac{P}{2\pi}\left(\phi\sin\phi - \frac{2R}{r}\cos\phi + \frac{5}{2}\cos\phi - \frac{r}{R}\right) \quad . \quad . \quad . \quad (9)$$

B and Q are shown graphically in Figs. 13 and 14. The distribution of N is the same as for Q in load Case A, *cf.* Fig. 7.

Load Case D.

Load Due to a Locally Applied Force in the Tangential Direction at the Distance R, Fig. 15.

The stresses in the frame under this load are obtained when a moment of the value $M = P(R-r)$ is superposed on the load Case C. The distributions of B, N, Q are then as follows:—

$$B = \frac{PR}{2\pi}\left(2\sin\phi - \frac{r}{R}\phi\cos\phi - \frac{r}{2R}\sin\phi - \phi\right) \quad . \quad . \quad (10)$$

$$N = \frac{P}{2\pi}\left(\phi\cos\phi + \tfrac{1}{2}\sin\phi\right) \quad . \quad . \quad . \quad . \quad (11)$$

$$Q = \frac{P}{2\pi}\left(\phi\sin\phi + \tfrac{1}{2}\cos\phi - 1\right) \quad . \quad . \quad . \quad . \quad (12)$$

The distribution of the bending moment is shown in Fig. 16. The run of N is the same as N in load Case C for $r/R = 1$ and as Q in load Case A with $r/R = 1$, Fig. 7. Q in load Case D has the same run as Q in load Case C with $r/R = 1$, Fig. 14.

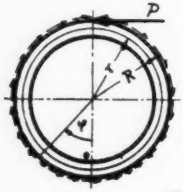


Bild 15 (links). Lastfall D Tangentialbelastung (Abstand R)

Bild 16 (rechts). Biegemomente bei Tangentialbelastung (Abstand R).

Fig. 15.
(Left.) Load Case D.
Tangential load (distance R).

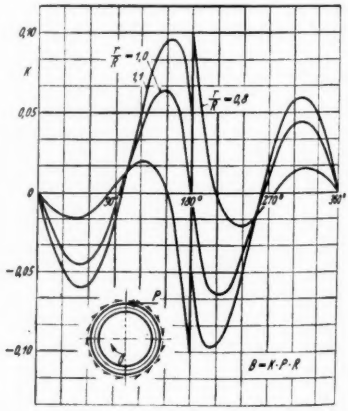


Fig. 16.
(Right.) Bending moment with tangential load (distance R).

IV. Numerical Example.

It is required to determine the stresses in an annular frame with the ratio $r/R = 1.1$ under the following load, Fig. 17.

By the resolution of P we obtain the following fundamental loads:—

Load Case A: $0.9\,P = 1{,}800$ kg. acting radially.
,, C: $0.4\,P = 800$ kg. acting tangentially.
,, D: 40 mkg.

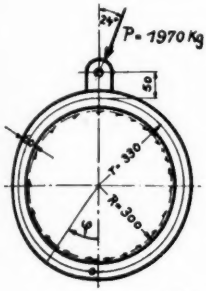


Bild 17 (links). Beispiel für eine Spantbelastung.

Bild 18 (rechts). Biegemomente und Normalkräfte.

Fig. 17.
(Left.) Example of a frame bulkhead loading.

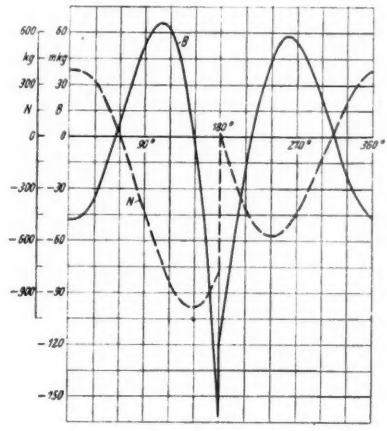


Fig. 18.
(Right.) Bending moments and normal forces.

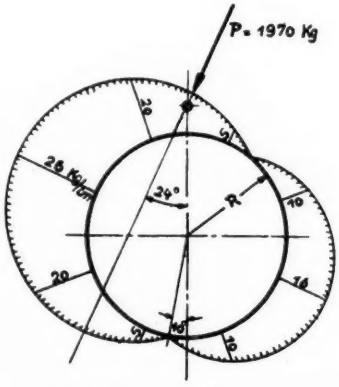


Bild 19. Größe und Verlauf des am Spant angreifenden Schubflusses

Fig. 19.
Distribution and magnitude of the shear flux on the frame.

The resultant bending moment curve is found either by calculation by superposing the results from equations (1), (7) and (4) or by graphical superposition (tracing) of the bending moment curves from the fundamental loads as represented in Figs. 5, 13 and 9. The same method is used also for the determination

of the resultant distribution of the normal and transverse forces. Knowledge of the longitudinal stresses from the bending moments and normal forces is of the greatest interest.

TABLE 1.

VALUES OF THE BENDING MOMENTS ACTING IN THE FRAME DETERMINED BY CALCULATION IN MKG.

Load case \ φ°	0	90	180	180	270	360
A	−47.2	+53.9	−141.5	−141.5	+53.9	−47.2
B	0	−3.0	0	0	+3.0	0
C	0	+2.7	−20.0	+20.0	−2.7	0
Result	−47.2	+53.6	−101.5	−121.5	+54.2	−47.2

TABLE 2.

CALCULATED VALUES OF THE NORMAL FORCES ACTING IN THE FRAME IN KG.

Load case \ φ°	0	90	180	180	270	360
A	−378	−450	−378	−378	−450	+378
B	0	+41	−400	+400	−41	0
C	0	−39	0	0	+39	0
Result	+378	−448	−778	+22	−452	+378

Tables 1 and 2 contain a few intermediate values determined by calculation. Fig. 18 shows the final curves for the bending moments and normal forces in the annular frame.

For the determination of the dimensions of the riveting or the welded seam between the annular frame and the shell it is necessary to know the distribution of the shear flux. It is calculated by the method described in Chapter II and the distribution for the annular frame load concerned is shown in Fig. 19. According to this the maximum shear flux is 26 kg./cm.

V. RANGE OF VALIDITY.

1. The calculations and their results hold for annular frames in which the depth of the cross-section is small in relation to the radius of curvature r. In this case the behaviour of the curved bar is similar to that of a straight one. The distribution of the stresses has therefore been assumed as following the rectilinear law and, further, it is assumed that the cross-sections remain plane. The influence of the longitudinal and transverse forces on the displacement quantities has been neglected.

2. The flexural stiffness of the shell plate is assumed as being small in relation to that of the annular frame.

3. No account is taken of the variation of the outline of the frame from the circular form due to the elastic deformation.

REVIEWS.

FIGHTER PILOT: A PERSONAL RECORD OF THE BATTLE OF FRANCE.
B. T. Batsford, Ltd. 1941. 6/-.

The operative word in the title of this book is "Personal"; it has the transparent sincerity of a diary or a home letter, and was obviously written as a record of the author's own experiences, with little thought of publication. This gives us plenty of untidy writing, such as: "... We saw a collection of bomb-craters where several sticks of anti-personnel ('that means *you*' I thought to myself with a curious shock) bombs had fallen near the Battles, one of which was 'written off' (destroyed)"; but it also gives us the stark beauty of: "At midnight I rose and shook hands with the Frenchman, and we wished each other the luck we knew we needed. He was killed the next day." ... "Most of the boys lay in the soft leaves under the stars."

The story of the "thin blue line" which held out against the Luftwaffe during the last days of the French campaign has been told several times already, but its epic quality loses nothing in the re-telling. Squadrons 1 and 73 will go down to history with the bowmen of Agincourt and the sailors who met the Armada. From the first week of the war until June 18th—the day before Marshal Pétain's request for an Armistice—these pilots were fighting in France; and the quality of their fighting may be estimated from Squadron 1's record of 140 enemy aircraft destroyed, for the loss of three pilots killed, two wounded and one taken prisoner.

From September, 1939, until the opening of the German offensive on May 9th, 1940, the narrative tells of a life which carries us back not one year but twenty-five. Like their fathers before them, these young men spent their leave playing games behind the lines, fraternising with their French fellow-pilots, and painting the nearest town red. There is a familiar ring in their jubilation over the first enemy machine shot down (they still regretted killing the pilots in those days), their treatment of the first prisoner—dined and wined in their Mess, in true "Dawn Patrol" style. Men who had to bale out were still collected by the nearest French unit and returned in a hilariously intoxicated condition to their headquarters. There is still the pretty barmaid—Susette or Germaine—still the stubborn peasant boy, muttering after the German who bombed his horses and his fellow-workers: "Oui, je te casse la gueule, toi!" Then, all of a sudden, comes the change. For six weeks the squadrons did nothing but fight and fly, moving back from place to place to keep pace with the French retreat. The effect on their nerves was evident; the narrative tells of exhausted men quarrelling and snapping at each other, often on the brink of tears, falling asleep over their food, or lying awake half the night from over-tiredness. It says a great deal for the Squadron-Leader that his men held out at all, and still more that he brought them back to England without a series of fatal crashes due to exhaustion. No less than ten D.F.C.'s were awarded to Squadron 1 for its work during these last weeks in France.

Service anonymity is somewhat humorously respected by the use of christian and nicknames throughout, especially as captions to excellent photographs, many of which have appeared elsewhere with full names printed under them. We spent an amusing half-hour identifying "the Bull," "Johnny," "Boy," "Hilly," "Leslie," and the rest—not to mention the author himself. Good luck to you, Fighter Pilot Paul R——!

AIR NAVIGATION.

F. G. Brown, B.A., B.Sc. Chapman and Hall. 32/-.

It is a generally acknowledged fact that navigators never see exactly eye to eye with one another, that is to say, each has his pet method of performing or calculating any particular observation or computation, and in most cases will stick unyieldingly to the view that his way is the best (quite naturally, too, as obviously he is well experienced and a fast worker at familiar formulæ) unless he is introduced to some new method which definitely simplifies, shortens or otherwise offers considerable and material advantages over his own.

The author of the volume under review is no exception to the above rule; the general presentation of his teaching makes one aware that whilst he is well learned in all the subjects dealt with, his leaning to any certain method, and consequent bias by stressing its use as superior to others, is perhaps a little too emphatic. For instance, he propounds fully on the use of the all Haversine formula and gives little more than mention of the more usual formulæ. A whole chapter is devoted to analysis of Hughes' tables and their use is repeatedly recommended, whereas, of course, there are many other short methods of spherical triangle solution available which are equally good, and some perhaps better.

The book, however, is really quite excellent and gives in a pleasant way, if perhaps unorthodox manner of phraseology for a text book, a clear account of the various problems, together with a concise explanation in most cases of their solution. These explanations are illustrated with frequent simple diagrams, and another good feature of the book is the number of examples and exercises set for the student to attempt himself.

The scope of the work includes spherical trigonometry, position-finding by sextant observation and magnetic deviation as its main subjects. Most of the chapters are followed by a useful summary of findings. The author becomes quite verbose at times, and uses many analogies to explain points, yet on other occasions skims quite suddenly onwards, probably assuming in a moment of forgetfulness that the student has already grasped something referred to previously in but the briefest manner. Remarks relating to particular chapters are appended:—

Chapter I, entitled "The Fundamentals," introduces the reader to the form of the earth and celestial sphere and contains many definitions. The suggestion to use ping-pong balls for three-dimensional diagrams is commendable, even if it appears amusing. The chapter is confusing in one or two places and one gross mis-statement to the effect that latitude and longitude never refer to any position other than the observer's position will probably upset the beginner completely.

Chapter II and III deal in a clear and concise manner with elementary mathematical and trigonometrical solutions of plane and spherical triangles, the latter chapter containing a good explanation of the principles of logarithms. The use of Inman's tables is recommended, but Norie's "Air Tables" will cover all requirements of the air navigator, as they were designed specifically for this purpose and are less bulky; they contain Haversine tables from 0° to 180°.

Chapter VI explains the various properties of a single position line very clearly. It is a pity that determination of moonrise and moonset is disposed of in one line. Again, later in the book, the equation of time is lightly dismissed in a similar manner merely by saying "We do not have to bother about this nowadays." Such an attitude will not help the student if at some future date he has to make use of a Nautical Almanac in lieu of an Air Almanac.

On page 108 an error appears; the formula for departure contains a secant, whereas, of course, it should be a cosine. It is commendable that the reader is encouraged to arrange his own lay-out of calculations.

Chapter VIII contains a quite straightforward explanation of great circle and composite sailings.

Chapter X, dealing with magnetic deviation, is a well detailed discourse, but unfortunately lacks a summary. The many black and white diagrams would have been improved and more clearly grasped if red and blue poles had been represented in appropriate colours.

The final chapter, No. XV, upon wind problems, relative motions, etc., is excellent. All is clearly explained and the author deals with the most difficult problem first in an efficient manner, and consequently the more simple ones are easily grasped later.

Altogether a useful book which deals with its subject matter in a practical manner and delves further where deeper theoretical knowledge may be desired for examination or other purposes.

FIRST PRINCIPLES OF FLIGHT.

D. Hay Surgeoner, A.F.R.Ae.S. Longmans, Green and Co. 1941. 3/6.

" First Principles of Flight " is the first of a series of five practical textbooks planned to provide a comprehensive and balanced course of air training for cadets and new recruits to aviation.

The remaining books in this series to be published, all written by the same author, are " Aircraft Construction and Operation," " Aero Engines," " How to Fly," and " Navigation and Meteorology."

A wide field is covered in a small compass so that the writing has to be concise. Judging by the present volume these text books will prove valuable to those students who really are anxious to learn and who have teaching facilities for fuller explanations.

The ground covered in this volume is the Atmosphere, Fluid Motion, Aerodynamics, Stability, Control and Airscrews. Any air training cadet who fully grasps the contents of these chapters will have a sound knowledge of the principles of flight which will prove invaluable to him. For those who intend to stay in aviation after the war such knowledge is necessary if they wish to make any progress at all, and, during the war, the more they know about the machine they have to maintain the better.

One looks forward to the remaining four volumes in this course. They should start many who are now only mildly interested along a road which may lead them anywhere. But they will not find it always an easy road to travel unless they put their whole energy into travelling along it.

RULE BRITANNIA.

By Cecil King. The Studio Publications. 1941. 12/6.

To publish a serious work with a " catchpenny " title is always a mistake, since it automatically repels the very readers who would appreciate it most. Despite its name and the explosive seascapes with which it is so liberally decorated, this book is not intended as a Christmas present for a twelve-year-old; it is a worthwhile account of English sea-power, written with insight, humour, and a background of historical and strategic knowledge. Only one chapter—that entitled " The Fleet Air Arm "—is of direct aeronautical interest, but it is significant that there is scarcely an engagement of the present war in which mention is not made of aircraft. Even the far-off *Graf Spee* action was helped by an observation aeroplane catapulted from H.M.S. *Ajax*.

Here, for the first time, we read of the *Jervis Bay*, the *Graf Spee* and the *Altmark*, the *Rawalpindi*, the *Bismarck*; the actions off Norway, Dunkirk and Greece; the Battle of Matapan; the clashes at Oran and Dakar, not as isolated incidents, but in their relation to the general strategy of the war. It is interesting to learn that the convoy system was adopted as far back as 1373, and that submarines were operating in the American Civil War.

We cannot help feeling that the author is optimistic in his comment on the withdrawals from Norway, France and Greece, that: " The superb manner in

which the Royal Navy, the Army and the Royal Air Force combined, in the finale to these events, had the effect of greatly enhancing British prestige"; but such optimism is in the true "Rule Britannia" spirit which leads to the winning of wars.

FLYING FLEETS.

By S. Paul Johnston. Duell, Sloan and Pearce, Inc., New York. 1941. $3.

This account of U.S. Naval Aviation is written in a breezy and straightforward style which goes well with its subject. If the author thinks an idea is "a wow," he says so—and does not waste his type-setter's time by writing that it "possesses manifest advantages." In spite of this unconventional approach—or possibly because of it—the 64 pages of text present a logical, complete and well-documented survey of the American Naval Air Fleet, from its inception in February, 1911, up to the present day. Many readers will learn with surprise that the first deck landing dates back to January, 1911, and the first catapult launching to 1912, while the famous Naval Air Station at Pensacola was founded in 1914.

By the end of the last war there were 21 naval aviation establishments in the U.S.A. and 22 bases overseas, from which American aircraft helped in convoy work and in locating mines and submarines. In the following year, the first Atlantic air crossing (as distinct from the first *non-stop* crossing made by Alcock and Whitten Brown) was achieved by the American flying-boat NC-4.

An unusual feature in this book is the grouping of pictures at the end. The proportion of pictures to text (122 : 64 pages) is perhaps rather overwhelming, but the photographs are of great historic interest and intrinsic beauty. Particularly striking is that of the airship Hindenburg moored at Lakehurst, in which, by an optical illusion, the airship at first glance looks like a bomb falling into the heart of the landing-circle. A significant diagram shows the defence areas that must be patrolled by U.S. aircraft; on it is marked "The Atlantic Narrows—only 1,860 miles wide." "Only" 1,860 miles . . . shades of Louis Blériot!

The volume is one of a series of three, of which the first—"Horizons Unlimited"—a general history of aviation, has already appeared. We shall look forward to the promised third volume, dealing with the U.S. Army Air Corps.

MONTHLY NOTICES.

DECEMBER, 1941.

Wilbur Wright Memorial Lecture, 1942.

The 30th Wilbur Wright Memorial Lecture will be read next May by the Rt. Hon. Lieut.-Colonel J. T. C. Moore-Brabazon, M.C., M.P., a Fellow and Vice-President of the Society.

Office Closing.

The Offices of the Society will be closed from Thursday, December 25th to Sunday, December 28th, both days inclusive.

Society of British Aircraft Contructors' Scholarships.

Five scholarships in the aircraft industry have been awarded for 1941 in the fifth year of the scheme financed by the Society of British Aircraft Constructors and administered by the Royal Aeronautical Society. In addition, under an extension of the scheme, nine boys already employed in the industry have been picked out for special S.B.A.C. apprenticeships for training in works management, works production and other branches of aircraft engineering.

The five new scholarship holders, who were selected from a large number of applicants by the Joint Committee representing the two Societies, are as follows. The names are given in alphabetical order.

Ronald Glover Aldred, of 87, Lord Haddon Road, Ilkeston, Derbyshire. Age 17.

Peter Frederic Crawley, of 29, Putnoe Lane, Bedford. Age 16.

John Radford, of 147, Curzon Street, Long Eaton, Notts. Age 17.

David Kenskett Saunders, of 189, Main Road, Kesgrave, Ipswich. Age 17.

Leslie Wookey, of 38, Jones Street, Blaenclydach, Tonypandy, Rhondda. Age 17.

The scholarships are specially intended to attract to the higher ranks of the industry lads whose financial circumstances would make it impossible for them to take up an aircraft apprenticeship as distinct from the ordinary trade apprenticeships.

Each scholarship holder is awarded a sum sufficient, in addition to the apprentice's wages paid him by the company to which he is attached, to bring his income up to £2 17s. 6d. a week. Each scholarship will ordinarily be held for four years, subject to satisfactory reports of the candidate's progress in the works and in the course of his technical education.

The scholarships are held with one or other of the leading aircraft or aero engine constructing companies. The training given prepares each boy for a post on the design or works production side of an aircraft or aero engine factory. It takes him through the workshops and gives him a period of instruction in the drawing office. He may also spend some time in the firm's research department. In addition, each scholarship holder is expected to attend technical classes to enable him to qualify at the end of his time for Associate Fellowship of the Royal Aeronautical Society.

Election of Members.

Fellows.—Rowland Henry Bound (from Associate Fellow), Frank Radcliffe (from Associate Fellow).

Associate Fellows.—Louis Massey Hilton (from Associate), John Edward Serby, William Thornton Slater, John Anthony Crosby Warren.

Associates.—Basil Peter Brooker (from Student), Patrick Macartney, Ronald Horace Morgan, Oswald Wright.

Graduates.—James Joseph Browne Houston (from Student), John Menzies Kay, Hugh McLennan Kendall (from Student), Donald McLean, Bernard Walter Martin (from Student), Raymond William Henry Stevenson.

Students.—Alan Barker, Peter Llewellyn Bisgood, Leslie Ernest Bishop, Robert Albert James Brown, Reginald William Cooper, Arthur Joseph Clifton, William Edward Hamilton Dutton, Eric William Pendle Harris, John Ernest Hommert, Percy Howlett, Edward John Hudson, Charles Henry Jones, Jacques A. Kirk, Charles Geoffrey Miller, Wilfrid Norwood Neat, Joseph McAdam Rainey, Edwin Albert Redwood, William Bryan Richardson, Douglas George Sedge, Arthur Frederick Toe.

Companions.—Alfred Peter Bond (from Student), Robert Bryce Farmiloe, George Ingram, Roland Stanley Pinkess.

Annual Subscriptions.

Members are reminded that their subscriptions are due on January 1st, 1942. The following are the current rates:—

	Home. £ s. d.	Abroad. £ s. d.
Founder Members	2 2 0	2 2 0
Fellows	4 4 0	3 3 0
Associate Fellows	3 3 0	2 2 0
Associates	*2 2 0	*2 2 0
Graduates (age 21-25)	2 2 0	2 2 0
,, (age 26-28)	2 12 6	2 12 6
Students	1 1 0	1 1 0
Companions	2 2 0	2 2 0

* £1 1s. 0d. without JOURNAL.

Discussions.

In accordance with the notice which appeared in the JOURNALS for July, August and September, 1941, the following discussions have already been held:—

1. The Future of British Civil Aviation.
2. Drag Reduction.
3. Application and Correlation of Wind Tunnel and Full-Scale Testing.

Further discussions are being arranged, provided a sufficient number of members indicate their wish to attend, on:—

4. Drawing Office Methods.
5. Vibration Problems.
6. Tolerances, Limits and Inspection.
7. Control Surface Design.
8. Compressibility Effects.

Members are reminded that they will not receive an intimation of the date and place of any of the discussions unless they write in to the Secretary and indicate their desire to attend.

Advertisements.

The fact that goods made of raw materials in short supply, owing to war conditions, are advertised in the JOURNAL should not be taken as an indication that they are necessarily available for export.

Graduates' and Students' Section.

An invitation has been extended to members of the Graduates' and Students' Section to attend the following meetings of the Graduates' Section of the Institution of Automobile Engineers. Membership cards should be shown at the door when attending the meetings at 12, Hobart Place, Victoria, S.W.1. Other meetings will be announced later.

Sunday, December 14th, at 2.30 p.m. Paper on "The Design Department" by J. B. Perrett Esq. Chairman: P. Kidner Esq (President of the Institution).

Sunday, January 11th, 1942, at 2.30 p.m. Paper on "Some Application of Photography to Engineering" by B. Eyden Esq.

Corrections.

The authors of the references on pages 392 and 416 of the Abstracts in the November JOURNAL to "Elements of Pendulum Dampers" should read "T. S. Wilson and R. W. Zdanowich."

Additions to the Library.

Pamphlets in Italics, with location reference following in brackets.
Books marked * or ** may not be taken out on loan.

A.a.294.—Simple Experiments in the Theory of Flight. By M. C. Nokes. Wm. Heinemann. 1941. 3/-

*B.g.106,107.—Fiches de Documentation. (Loose-Leaf Folders.) Union Syndicale des Industries Aéronautiques. 1936/38.

BB.f.44.—Meteorological Instruments. W. E. Knowles Middleton. University of Toronto Press. 1941. $3.25.

C.d.145.—H.M.A. R.34. E. M. Maitland. Hodder & Stoughton. 1920. 4/6.

D.b.166.—Quelques Aperçus sur l'actuel Effort Technique Aérien Français. Ministère de l'Air. 1933.

D.b.167.—L'Air. (Special Aeronautical Number.) 1938.

D.c.87.—L'Illustration. (Special Airports Number, containing full details of new airport at Le Bourget.) 1938.

E.a.11.—Teach Yourself Mechanics. By P. Abbott. English Universities Press. 1941. 2/6.

E.c.22.—*The Technical Cohesive Strength of Materials. By D. J. McAdam. (Preprint of paper to be read at A.S.M.E. Technical Meeting, Dec. 1-5, 1941.)* (Y.13.a.13.)

E.f.90.—Metal Aircraft for the Mechanic. By J. Healey. (3rd Ed.) Sir Isaac Pitman. 1941.

EE.c.62.—Understanding Aero Engines, by Question and Answer. W. Hazell. English Universities Press. 1941. 2/6.

EE.j.32.—*The Axial Vibration of Diesel Engine Crankshafts. By Ralph Poole. (Preprint of paper to be read before the Inst. of Mech. Engineers, Dec. 19, 1941.)* (Y.7.b.5.)

*G.b.39.—Bauvorschriften für Flugzeuge. D.V.L., Berlin. 1928.

G.e.E.51.—*Pitting and its Effect on the Fatigue Limit of Steels Corroded Under Various Conditions. By D. J. McAdam and G. W. Geil. (Preprint of Paper read at 44th Meeting of Am. Soc. for Testing Materials, June, 1941.)* (PG.6/16.)

G.e.J.18.—*Elmet Metals. Compound Electric Metals, Ltd.* (Y.13.c.E.)

G.f.22.—Lessons in Arc Welding. (2nd Ed.) Lincoln Electric Co. 1941.

J.b.13.—*India Meteorological Department: Scientific Notes*:—
Vol. VIII, No. 91: The Hindu Kush Earthquake of November 21, 1939. By S. M. Mukherjee and A. R. Pillai. 1941.

J.g.188.—Visibility in Meteorology. (2nd Ed.) By W. E. Knowles Middleton. University of Toronto Press. 1941. $2.50.

L.d.68.—*Elementary Navigation for Air Training. By C. Barrington Gyford. Longmans, Green and Co.* 1941. 1/-. (PL.1.b.5.)

M.a.24.—Electrical and Radio Notes for Wireless Operators. (A.P.1762.) Air Ministry. 1941. 3/6.

*OO.115.—International Conference on Aerial Navigation. Chicago. Proceedings. 1893.

Q.a.143.—British Standards Institution, Handbook. July, 1941. 1/6.

Q.d.50.—By Joint Efforts we shall end Hitlerism. S.C.R. (Voks). Moscow. 1941.

R.b.226.—The Conquest of the Air. By J. Alexander. S. W. Partridge & Co. 1902.

R.b.227.—Aerial Navigation. By F. Walker. (1st Ed.) Crosby Lockwood. 1902.

R.b.228.—Progress in Flying Machines. By O. Chanute. New York. 1894.

R.b.229.—Travels in Space. By E. S. Valentine and F. L. Tomlinson. Hurst & Blackett. 1902.

R.c.266.—Navigating the Air. Aero Club of America. Doubleday Page. New York. 1907.

R.c.267.—Artificial and Natural Flight. Sir Hiram S. Maxim. Whittaker & Co. 1908.

R.e.47.—A History of Aeronautics. By E. C. Vivian and W. Lockwood Marsh. Wm. Collins. 1921.

RR.112.—*Practical Aerodynamics. By B. F. Baden-Powell. Aeronautics Office. (Undated.)* (Y.21/P.)

*S.e.32.—*Lord Gort's Despatches from France and Belgium*, 1939-40. (*Supplement to London Gazette, 10th October*, 1941.) (Y.17.c.F.)

S.b.104.—The Work and Training of the Royal Naval Air Service. Illustrated London News. (Abt.1917.) 2/6.

S.b.105.—The Work and Training of the Royal Flying Corps. Illustrated London News. (Abt. 1917.) 2/6.

T.b.77.—My Flight to the Cape and Back. A. J. Cobham. A. & C. Black. 1926. 1/6.

*T.c.41.—Iceland: the first American Republic. By Vilhjalmur Stefansson. Doubleday, Doran & Co. New York. 1939. $3.50. (Autographed.)

TT.a.36.—Drama in Mid-Air. By H. Park Bowden. John Ouseley. 1908.

WB.21.—Journal and Proceedings of the Royal Society of New South Wales. Vol. LXXIV, Part 4. 1941.

UL.3.—*Institute of Physical and Chemical Research, Tokyo: Scientific Papers*:—

Nos. 1028-33 (June, 1941), and Nos. 1034-35 (July, 1941).

UL.6.—*Aeronautical Research Institute, Tokyo: Reports.* (1941):—

No. 206.—The Vibration and Sound of a Revolving Thin Plate (Acoustical Model of Airscrew Flutter). By J. Obata and others.

No. 207.—On the Nature of a Satellite in the X-ray Pattern of *a*-Crystals, and the differentiation of a new Phase *a'* by the Surface-Recrystallization Method in certain Ternary Alloys. (I). By S. Kiuti.

No. 208.—The Characteristics of the Aerofoil with Discontinuities along the Span, with special reference to the effects of Cut-Out. By T. Okamoto.

No. 209.—An X-Ray Study on the Mechanism of the Splitting Phenomenon of *a*-Crystals. By S. Kiuti.

No. 210.—Resistance Welding of Light Alloys. A.R.I. Resistance Welding Research Committee (IN JAPANESE, with Summary in English.)

*U.U.c.—*National Advisory Committee for Aeronautics: Technical Memoranda:*—

No. 983.—Temperature recording in high-speed Gases. By E. Eckert. (Z.V.D.I., 26.10.40.)

No. 985.—Tables for Computing Various Cases of Beam Columns. By J. Cassens. (Luftfahrtforschung, 20.3.41.)

No. 986.—New Frictional Resistance Law for Smooth Plates. By F. Schultz-Grunow. (Luftfahrtforschung, 20.8.40.)

J. LAURENCE PRITCHARD, *Secretary and Editor.*

THE USE OF DUMMIES IN THE CAMOUFLAGE OF OPERATIONAL AERODROMES.*

By E. Z. Yassin.

"*Air Fleet News*," *U.S.S.R.*, *Vol.* 23, *No.* 5, *May*, 1941, *pp.* 432-439.

Translated by L. J. Goodlet.

Dummies are particularly suitable for use in camouflaging operational aerodromes; they not only serve to mask the aircraft and equipment stationed thereon, but also make it possible to give the flying field the aspect of being unusable for flying purposes.

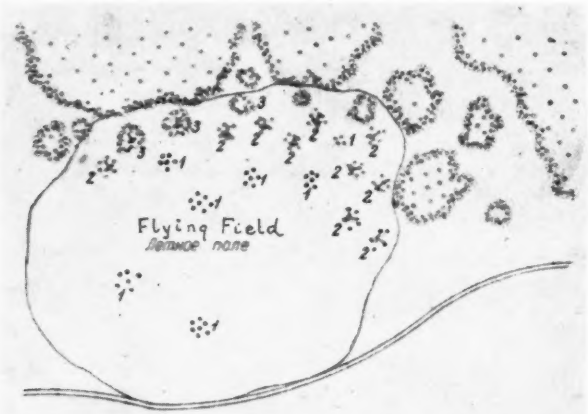


Рис. 1. Схема маскировки летного поля и самолетов группами ложных деревьев.

1—группы ложных деревьев для маскировки летного поля; 2—самолеты, замаскированные среди ложных деревьев; 3—самолеты, замаскированные среди действительных деревьев.

FIG. 1.

Scheme for the camouflage of a flying field and aircraft by means of groups of dummy trees:—

1. *Groups of dummy trees for masking the flying field.*
2. *Aircraft masked by dummy trees.*
3. *Aircraft hidden among actual trees.*

In recent wartime practice, dummies have been extensively used for aerodrome camouflage, and have proved particularly effective, since an enemy flying over the area in which an operational aerodrome is situated, will usually omit to take

* R.T.P. Translation No. 1271. Published by permission of the Ministry of Aircraft Production.

notice of dummies imitating local features of the landscape, and concealing the purpose for which the terrain is actually being used.

Such dummies should preferably be made of local materials by the personnel of the unit itself, with the minimum expenditure of time and labour. They should be light in weight and simple in construction. Even if roughly made, they should sufficiently well imitate their prototypes when observed from a certain height. The dummies should not impede the ordinary work on the aerodrome, some of the dummies should therefore be made easily portable.

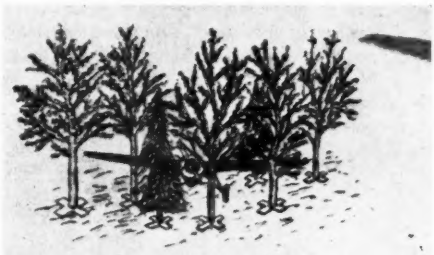


Рис. 2. Схема маскировки самолета макетами деревьев.

FIG. 2.

Scheme for the camouflage of an aircraft by dummy trees.

Рис. 3. Легкий передвижной макет дома.

FIG. 3.

Light portable dummy house:—

1. Wire; 2. Poles; 3. Plywood; 4. Camouflage screen; 5. White fabric; 6, Painted details; 7. Nails.

Discovery of a properly camouflaged aerodrome is possible only in the following cases:—

1. If the situation of the aerodrome and the nature of the camouflage have been disclosed to the enemy by agents' reports.
2. If the camouflaged condition of the aerodrome is disturbed on the appearance of the enemy.
3. If it is possible for the enemy to discover the method of camouflage by an extensive inspection of aerial reconnaissance photographs.

The possibility of using stereoscopic aerial photography suggests the use of three-dimensional (solid) dummies or mock-ups. In many cases, however, it

will be possible to use two-dimensional (or flat) camouflage, to imitate three-dimensional, solid objects—*e.g.*, by painting the surface of the runways, covering with suitably painted nets or screens, etc.

Solid (three dimensional) mock-ups, or dummies, are preferable for the imitation of objects rising considerably above ground level—*e.g.*, trees, stacks, stumps, animals, etc.

Flat, two-dimensional camouflage can be used to imitate features which do not project considerably above the surface of the ground—*e.g.*, roads, footpaths, marshy spots, etc.; or features depressed below ground level—*e.g.*, holes, ditches, gullies, craters, etc.

The preparation of dummies in advance, relieves the operational unit of extra work and time spent in camouflaging their site, but has the following disadvantages:—

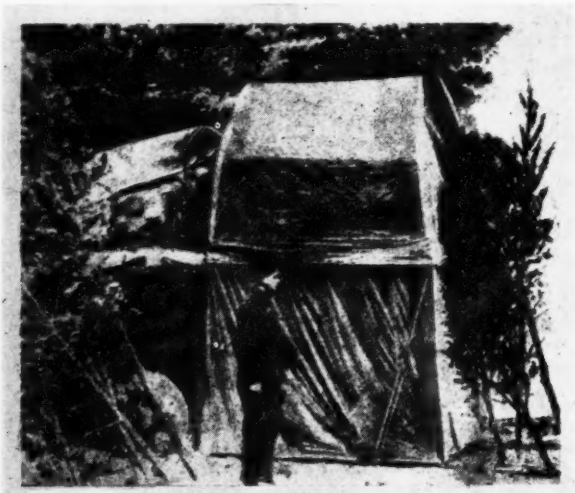


Рис. 4. Маскировка самолета под палатку туриста.

FIG. 4.

Camouflage of an aircraft by a camper's tent.

1. The carriage of the dummies imposes an additional strain on the means of transport, already over-strained by wartime needs.
2. Objects of the same kind may have distinctive peculiarities in different regions.
3. The particular characteristics of each region involve the use of a variety of different dummies, the number of which may become excessive.
4. On removal to another site, the operational unit has a great number of dummies to transport, or abandon them, if unusable on the new site.

This is a further proof that it is preferable to prepare the required dummies on the spot.

Occasionally, dummy aircraft have been prepared in quantities, on an industrial scale. Superficially regarded, this appears a very efficient method, since the dummies can be made almost perfect imitations of the originals. Distributed over an aerodrome, they cannot fail to attract the attention of the enemy. Recent wartime experience, however, has shown this method to be of doubtful value.

Aircraft dummies " displayed " on a dummy flying field, fail to deceive, since only a *dummy* aerodrome—and a very badly planned one—would openly display aircraft. It is therefore necessary to camouflage even a dummy aerodrome, and it would appear best to construct the dummy aircraft on the spot, and camouflage them as carefully as the real ones. It will be unnecessary for the dummies to be exact replicas of the original aircraft, since in any case they will be visible to enemy observers only partially, through the camouflage.

Should the operational aerodrome adjoin a wood or forest, this can be made use of to conceal the aircraft. However, it is frequently found impossible to disperse the aircraft actually within the fringes of the wood, since the ground is usually rough and unsuitable. In such case, it is advisable to use groups of dummy trees, concealing the aircraft standing on suitable ground, but at the same time appearing to be a continuation of the fringe of the original wood. The natural appearance of these dummies will be enhanced by the proximity of the real wood.

Рис. 5. Группа макетов лошадей на летном поле.

FIG. 5.

A group of dummy horses on the flying field.

The spacing and arrangement of the dummies should match the general appearance of the terrain, and also be convenient for the operation of the concealed aircraft (Fig. 1).

The dummy trees must match their prototypes, in shape, colour, and structure. The best method, therefore, is to use real ones, cut from the interior of the wood, and disposed as required. They should be fitted with cross-shaped pedestals, to make them portable. Despite their many undoubted advantages, real trees used as camouflage have the one great drawback of withering, which limits the period of their effective use.

A more troublesome method of making dummies, is to use real trees, but deprive them of their foliage, and substitute imitation foliage (Fig. 2), made from suitably painted reinforced paper or camouflage fabric, attached to the branches by twine or wire. This allows the dummies to be used for a long time, while they are sufficiently good imitations of natural ones.

A third method, is to use poles for the tree trunks, affix a wire carcase representing the skeleton crown, and attach imitation foliage as above. This is the

most troublesome method of production, and should therefore only be used in regions where the supply of real trees is difficult or impossible.

Dummies of bushes or brushwood are usually made from the wire carcase mentioned above, covered with imitation foliage in the manner described.

If there are any buildings in the vicinity of the operational aerodrome, good use can be made of suitable dummy buildings for camouflage, to give the impression of an extension of the inhabited area.

These dummy buildings can be of different types and sizes, but must always match the actual buildings near the aerodrome, in appearance. When providing for such dummies, attention should also be paid to the possibility of using them to conceal aircraft and equipment, besides camouflaging the aerodrome. Their dimensions and construction should therefore be adapted for this purpose.

If it is asked whether this objective can be agreed with the necessity for closely copying the appearance of actual buildings, the answer is obviously in the affirmative. Assuming that a group of farm buildings—dwelling-house, outbuildings, stables, etc.—is imitated, it is obviously possible to make these dummies, depending on their external dimensions, suitable for the accommodation of aircraft, vehicles, etc., if their construction, materials, etc., are suitably selected.

Рис. 6. Ложный скирд соломы.

FIG. 6.
Dummy straw-rick.

A dummy building to accommodate an aircraft should be of robust construction, free from obstructions, and easily and quickly opened to permit entry or exit of the aircraft or vehicle.

Structures concealing a vehicle can be of simple and lighter construction. Dummies intended only to camouflage the flying field, can be quite light and portable. Fig. 3 shows such a dummy cottage, consisting of a framework covered with painted camouflage material, and placed on wheels for mobility.

A dummy dwelling-house concealing an aircraft can be built up of a framework covered with plywood or fabric. The opening for entry and exit of the aircraft should always be covered with fabric, matting, or sacking and capable of being quickly drawn aside. An imitation door or gateway can be painted thereon. Windows, log walls, etc., can be painted on the fabric as required. The roof can be imitated by plywood, fabric, matting, sacking, or camouflage screens. In winter, a snow-covered roof can be successfully imitated by means of white

fabric. A straw-thatched roof is represented by camouflage matting, or by other materials, suitably painted.

From the foreign press, it appears that dummies of even lighter structures than dwelling-houses and farm buildings can be usefully applied in camouflaging. Fig. 4 shows an aircraft camouflaged with an imitation of a camping tent frequently used by hikers, etc., in Western Europe. According to the " Sphere " journal (England), the instant readiness of the concealed aircraft is hardly affected by this method of camouflage.

Easily portable dummies include imitations of horses, cattle, and other farm animals. A small group of dummy animals, suitably arranged, have been found very effective in concealing the presence of any flying activities on the site. In other countries, dummies of the domestic animals most common there (*e.g.*, camels in Central Asia) could be substituted.

Several methods are available for making dummy animals. Among the simplest is the following:—Make a framework of wooden poles to the dimensions of the original, place it on trestles taking the place of legs and feet, and cover it with fabric, matting, or sacking. Manes, tails, etc., can be imitated by camouflage netting or tow. The dummy is then suitably painted, using glue or paste as a vehicle.

Рис. 7. Макет коровника и коровы для маскировки автосредств.

FIG. 7.

Dummy cowshed and cow, camouflaging a motor vehicle.

A dummy horse uses about 15 metres of poles, 4-5 cm. diameter, 1 kg. wire, 3 mm. thick, and 8 sq. m. fabric, matting, or netting; a dummy cow—about 17 m. poles 5-8 cm. diameter, 1½ kg. wire, 3-4 mm. thick, and 10 sq. m. material for covering.

No attempt should be made to make an exact copy of the animal; a rough impression of its external appearance is sufficient (see Fig. 5), omitting all details, which would in any case be invisible from the air. The dummies should be distributed over the aerodrome in natural-seeming groups.

From the point of view of camouflage, dummy ricks of straw, haystacks, etc., are particularly effective. These mock-ups are usually not made portable, and are used for the concealment of aircraft and vehicles. Dummy stacks and

ricks consist of a framework covered with camouflage fabric (Fig. 6). Size and shape are copied from the actual stacks or ricks as used in the locality.

In some cases, the impression of a hay-stack is given by the use of camouflage netting plaited with bunches of hay. This method has been frequently used during the present war in Western Europe. The foreign press mentions the camouflage of motor vehicles parked close under the walls of farm buildings, by a dummy pile of hay, one side of which is arranged to throw back when the vehicle is used, which can be done very quickly.

Other methods can be used for camouflaging vehicles, imitating actual objects in the terrain: Sheds, outhouses, stables, byres, etc. Fig. 7 shows a dummy cowshed, the walls being imitated by brushwood plaited into a camouflage netting, a dummy cow, tethered to the shed, and a stake fence. If such a dummy is correctly disposed and blended with the other features of the surroundings, it is very doubtful if an enemy observer could penetrate the deception.

Рис. 8. Ложный огород.

FIG. 8.

Dummy kitchen-garden.

To complete the illusion of an inhabited locality it is usual to complete the mock-up of buildings by imitating an adjacent kitchen garden. In some cases this " garden " can be located a little distance from the " buildings," in the direction of the flying field. Such imitations are very effective if planned as a continuation of actual gardens, since then any blemishes in the imitation will be screened by the natural appearance of the locality and the proximity of the actual garden.

Imitation gardens can be made from strips of camouflage screen or reinforced paper (Fig. 8), if they are arranged at the boundary of the flying field and do not have aircraft passing over them, since the camouflage screens will project over the surface of the ground. It is impossible to rely on quick removal of the camouflage strips, since they have to be pegged down and wired to the ground. Furthermore, it is in any case unpractical frequently to remove and replace such material.

If the mock garden is required to be on the runway and traversed by the wheels of the aircraft, it is better to make the camouflage by painting on the ground, or covering with a thin layer of sand, cinders, sawdust, or other material, imitating the light and dark strips indicating the presence of garden beds as observed from the air.

The same methods can be used to imitate ditches, channels, gullies, roads and other features of the terrain not projecting above the surface of the ground.

A disorderly accumulation of various dummies over the flying field of an operational aerodrome will not give the desired impression. The dummies should be used sparingly, and arranged to correspond exactly with the natural appearance of the locality. The more natural the look of the dummies and their arrangement, from the air (Fig. 9), the better their camouflage effect.

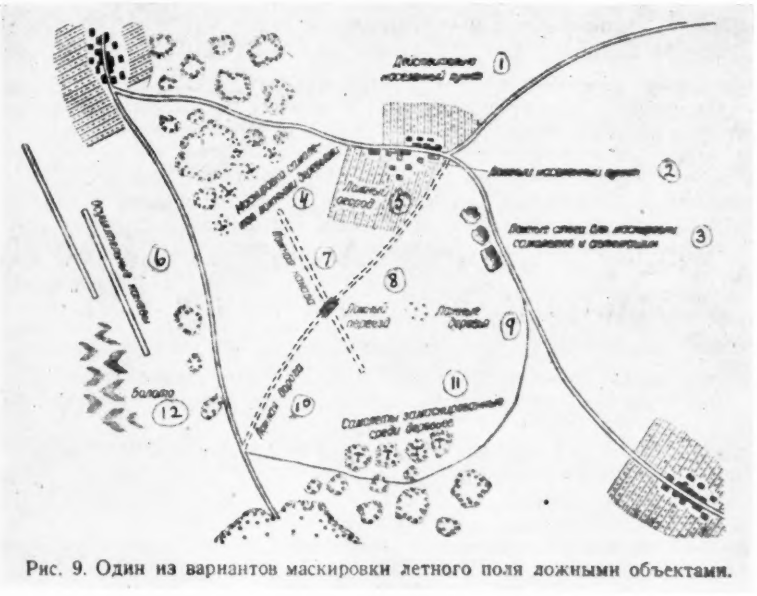


Рис. 9. Один из вариантов маскировки летного поля ложными объектами.

FIG. 9.

Suggestions for the camouflage of a flying field by dummies:—

1. *Actual dwellings.*
2. *Dummy dwellings.*
3. *Dummy stacks masking aircraft and vehicles.*
4. *Aircraft camouflaged by dummy trees.*
5. *Imitation kitchen-garden.*
6. *Drainage ditches.*
7. *Dummy ditch.*
8. *Dummy culvert.*
9. *Dummy trees.*
10. *Imitation road.*
11. *Aircraft hidden in trees.*
12. *Swamp.*

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ELEMENTARY NAVIGATION FOR AIR TRAINING.

By C. Barrington Gyford. Longmans, Green and Co. 1941. 1/-.

This 50-page pamphlet, intended for the pre-entry training of A.T.C. cadets, fulfils the object of *ab initio* textbooks; it imparts the necessary minimum of information with the maximum of clarity. There is a commendable absence of those " woolly " statements that so often arise from attempts to bring a complicated idea within the reader's grasp. In its short compass the book deals with latitude and longitude, variation and deviation, the plotting of course and track, the triangle of velocities, time-scales, navigation instruments and the effect on them of atmospheric pressure. The diagrams are particularly clear and good.

VISIBILITY IN METEOROLOGY. (2nd Edition.)
METEOROLOGICAL INSTRUMENTS. (1st Edition.)

By W. E. Knowles Middleton. University of Toronto Press, Canada (or Oxford University Press, London). 1941. Price $2.50 and $3.75, respectively.

The appearance of these two books, by a meteorologist of Mr. Middleton's standing, is particularly important at a time when the war has led to such a vast extension in all-weather and night flying. Both should prove invaluable to the meteorologists who are responsible for the pilots' safety.

The most important innovations in the first book are in Chapter V: " Applications to the Calculation of the Visual Range," where sub-sections have been added, dealing with visibility in fog and cloud, moonlight, starlight and twilight. Of special interest to the bomber pilot is the concluding paragraph: " Vertical and Oblique Visual Range," which gives references to German and English articles on this most topical subject. Chapter VII: " Empirical Visibility Meters," has been very considerably expanded. Under the new title " Instruments for the Measurement of the Visual Range," it now gives descriptions and diagrams of the principal types of telephotometer and transmission meter. A new Chapter X deals with fog forecasting, while the attention of camouflage experts should be drawn to the useful appendix on " The Visual Range of Coloured Objects." The value of the book is enhanced by its comprehensive bibliography and good index.

" Meteorological Instruments " has the distinction of being the first English book written on this subject for over 50 years. Hitherto, meteorologists who could not read Kleinschmidt's exhaustive treatise: " Handbuch der meteorologischen Instrumente " in the original, have been obliged to hunt for information scattered in a number of general works on Meteorology. Mr. Middleton's excellent classification divides meteorological instruments into those measuring Atmospheric Pressure, Temperature, Humidity, Precipitation and Evaporation, Surface Winds, Upper Winds, Clouds and Sunshine. A final chapter on Instruments for the Investigation of the Upper Air, contains invaluable information about sounding balloons, radio-sondes and radio-wave soundings. The book is liberally illustrated with very clear photographs and diagrams, and frequent references are given to original sources.

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ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
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(Prepared by R.T.P.)

No. 85. DECEMBER, 1940.

On the Calculation of the Quantity of Bombs Required for the Destruction of Various Targets. (A. S. Palchikov, Air Fleet News, U.S.S.R., Vol. 23, No. 7, July, 1940, pp. 27-31. R.T.P. Translation No. 1126.) (85/1 U.S.S.R.)

The nature of the target determines the number of bombs required as well as the methods of approach and bombing to be adopted. A railway station of average size will require at least 80 hits with 100 kg. H.E. with a fair sprinkling of splinter bombs in order to be put completely out of action for 5-6 hours.

Open tracks and small stations are usually badly protected and can be attacked from low altitudes. Cuttings with high embankments are specially vulnerable. Clay and sandy soil will require 100 kg. H.E. bombs, rocky soil 250 kg. bombs. Any risk of the bomb richochetting and rolling down the slope should be allowed for by fitting instantaneous fuses. Hydro electric power plants present a difficult problem. The power units in the dam will require at least five direct hits with 500 kg. H.E. bombs.

After reviewing other types of targets the author concludes that hasty or insufficient preparation for the raid will nullify the effect and lead to a possible waste of expensive material.

Some General Mathematical Considerations on the Possible Errors of A.A. Fire. (H. Brandli, Flugwehr und Technik, No. 9-10, 1939, pp. 247-248; No. 11-12, 1939, pp. 275-277; No. 1, 1940, pp. 9-12.) (85/2 Switzerland.)

The space position of a shell at a given time t is determined by the azimuth and elevation of the gun at the instant of firing W and the time interval $T=t-W$ which has elapsed. All shells which have been in the air for the same time interval T but were fired with different elevation and azimuth settings will lie on a surface which is symmetrical about a vertical axis passing through the zenith point of the gun. At any instant t the target aircraft will be on such a surface T and a hit at this instant is only possible if the gun has been fired at a time $W=t-T$, and if azimuth and elevation are appropriate. If azimuth and elevation at time W are in error, the shell at time t_1, although on the same T surface as the aircraft at the same instant t, will pass the target at a certain distance y_1. This distance is not necessarily the minimum distance y between shell and aircraft at some subsequent time $t+\Delta t_1$. The author shows, however, that the difference between y and y_1 is unlikely to exceed 3 per cent. If we neglect the motion of the aircraft target, *i.e.*, consider it fixed in space at time t, the shell

will pass this position at a minimum distance y_2 at time $t+\Delta t_2$. Unless y is very large, y_2 again will not differ from y by more than 6 per cent. Any one of the three vectors y, y_1 or y_2 can thus be employed to specify the accuracy of the fire of contact fuse ammunition. In the case of time fuses, however, the error is determined by the position of the aircraft at the instant of the shell explosion. Even if the shell is fired at the correct time W, therefore, the vector error x will depend on the fuse setting as well as on azimuth and elevation at time W. If the aircraft is assumed to be fixed at the instant t, the shell burst will occur at a distance x_1 from this fictitious position. This vector can also be employed for estimating the accuracy of fire. The percentage difference between x and x_1 depends primarily on the ratio of shell to aircraft speed and may thus be considerable ($\sim$ 50 per cent.).

In the training of A.A. personnel, it is very important that some idea of the progress achieved be obtained at an early stage and before actual firing trials are carried out. The author suggests that some of the vectors discussed could be incorporated in simple training devices, but no details are given as to the means of achieving this.

Fluid Flow in Pipe Lines and Fittings. Moore, J., Junior, Inst. Eng., Oct., 1940, pp. 1-13.) (85/3 Great Britain.)

The problem of determining the effect of changes in direction or cross section of pipes and pipe fittings on pressure loss in pipe flow is approached from two points of view, viz., determining the equivalent length of straight pipe and using straight pipe formulæ, or employing formulæ applicable only to the particular type of fitting. Following a theoretical treatment of the problem, experiments on different types of fittings are described, and calibration curves are reproduced. From these curves values of c and n in the formula $P=c\phi^n$ are derived, where P is the pressure drop and ϕ the rate of flow. It is emphasised that the "equivalent length" is dependent on the rate of flow, and the same value can only be used for all discharges if n is the same for the pipe as the fitting.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Economic Pipe Size with Transportation of Viscous and Non-viscous Fluids. (B. R. Sarchet and A. P. Colburn, Ind. and Eng. Chem. (Industrial Ed.), Vol. 32, No. 9, Sept., 1940, pp. 1249-1252.) (85/4 U.S.A.)

The economic pipe size, for which the sum of pipe and pumping costs is a minimum, has been derived for both the turbulent and viscous regions of flow. The resulting equations are represented by convenient nomographs. By solving the optimum diameter equations simultaneously with the critical Reynolds number, a convenient relation has been found to indicate whether any given flow will be turbulent or viscous in a pipe of optimum diameter. Although the optimum velocity of many liquids in turbulent flow runs from 3 to 4 feet per second, much lower optimum velocities are calculated for very viscous liquids.

The Analogy of Fluid Friction and Heat Transfer. (B. A. Bakhmeteff, Trans. A.S.M.E., Vol. 62, No. 7, Oct., 1940, pp. 551-553.) (85/5 U.S.A.)

The author discusses a previous paper by von Kármán (Trans. A.S.M.E., Vol. 61, 1939, pp. 705-710.)

According to the momentum heat transfer analogy of Reynolds the overall heat transfer number for turbulent convections $C_H=C_f/_2$ when C_f = friction coefficient. Now experiment shows that $C_H > C_f/_2$ and this discrepancy has been repaired by Taylor, Prandtl and von Kármán by introducing the effect of the laminar layer at the wall, across which the heat transfer is by conduction. The author questions the validity of the form of this correction factor on physical grounds and proposes an alternative treatment in which the Reynolds analogy is

expressed in terms of energy instead of momentum. This leads to the expression $C_H = C_f$ instead of $C_{f/2}$ after allowing for the effect of the laminar boundary layer

$$C_H = \eta C_f$$

where

$$\eta = 1/(1 + N\sigma/2\ C_f)$$

and

σ = Prandtl number.

Experimental results can be represented satisfactorily by making N = constant, although somewhat greater accuracy requires N to be of the form $N = N_0/_{\sigma m}$.

The Effect of Compressibility. (J. Ackeret, Flugwehr und Technik, Vol. 2, No. 1, Jan., 1940, pp. 18-20.) (85/6 Switzerland.)

It has been shown by Prandtl that the aerodynamic forces on a given wing profile at a given incidence and Mach numbers up to 0.6 are approximately the same as those acting on a transformed profile in incompressible flow. The transformation is very simple and amounts to an increase of all the ordinates of the profile (including incidence) in the ratio $1/\sqrt{(1 - M^2)}$.

A thin profile at a certain incidence is thus equivalent to a thicker profile at a larger incidence, *i.e.*, both lift and profile resistance increase with increase of Mach number M and high speed profiles must therefore be thin. Up to $M = 0.6$, the increase in profile drag can, however, be kept small. At higher values of M, the increase in drag becomes catastrophic and the simple Prandtl correction factor no longer applies. It is known that this rapid increase in drag is associated with the appearance of shock waves. The energy dissipated in such waves is, however, relatively small so long as M remains in the neighbourhood of unity and the author suggests that the increase in drag observed under these conditions is due to the reaction of the pressure wave on the boundary layer. Optical investigations have shown that at these high air speeds, the boundary layer breaks away in the neighbourhood of the maximum cross section and the aerodynamic shape of the wing is ruined. Experiments are in hand with a view to increasing the stability of the boundary layer and preventing separation at high Mach numbers. The author hopes to report on these at some future date.

Heat Exchanger for Aircraft (German Patent No. 673,301, Dornier Works, Friedrichshafen). (Flugsport, Vol. 31, No. 9, 26/4/39, Patent Section No. 7, p. 27.) (85/7 Germany.)

Principal claim: Heat exchanger, built into leading edge of wing or other parts of the aircraft exposed to the incident air stream, characterised by the fact that a number of heat transfer elements are arranged either in series or in parallel and inter-connected by means of suitable passages in such a way that the direction of flow of both the entry and exit air can be varied by the operation of shutters or their equivalent. The temperature of the exit air is thus controllable over wide limits. The diagrams accompanying the original abstract show a radiator element of the honeycomb type installed in a cylindrical tube forming part of the leading edge of the wing. Three control positions are shown in action:—

(1) The incident air enters through a slot in the lower edge of the wing nose and is led through a channel to the rear of the radiator. After passing through the radiator the heated air flows through a channel close to the leading edge of the wing.

(2) The incident air enters the front of the radiator through a passage near the nose and leaves through slots in the upper wing surface near the point of maximum suction.

(3) Same as (2), except that the heated air is collected in a channel inside the lower wing surface.

Shear Centre of a Leading-Edge Wing Beam. (H. W. Sibert, J. Aeron. Sci., Vol. 7, No. 12, Oct., 1940, pp. 520-523.) (85/8 U.S.A.)

Several years ago Hatcher (J. Aeron. Sci., Vol. 4, No. 6, pp. 233-238) outlined a method based on the least work of shear stresses for determining the shear centre of a sheet metal box spar of constant cross section. His analysis produced a double integral for the unknown shear stress at a chosen point and a second double integral for the moment of the shear stresses on a cross section, but he gave no method for evaluating these double integrals when the mathematical equation of the skin contour is unknown, which is usually the case in leading-edge wing beams. Later, Newell (J.S.A.E., Vol. 45, No. 3, pp. 385-388) obtained the shear centre of a leading-edge wing beam of constant cross section by evaluating two analogous double integrals by the strip method.

Previously, the author had reduced the double integral for the shear stress at a given point to a single integral, which could be evaluated by Simpson's rule when the equation of the skin contour was unknown, and had expressed the double integral for the moment of the shear stresses as an area, which could be measured with a planimeter.

Unfortunately, the author's final results were expressed in an unnecessarily complicated form, which decreased considerably their value to a designer. This defect is remedied in this article, and the two fundamental double integrals are so expressed that the calculations involved will be considerably shorter than those required for the strip method.

The Utilisation of Different Kinds of Wood in Built-up Airscrews. (K. Riechers, Z.V.D.I., Vol. 84, No. 20, 18/5/40, pp. 339-342.) (85/9 Germany.)

The efficient utilisation of large powers in a single airscrew operating at high altitudes necessitates the utilisation of blades of considerable width, since the number of blades which can be used is limited to three or four by the variable pitch mechanism, which otherwise becomes unduly complicated. At the same time the diameter of the blade is fixed, since the tip speed must not exceed the velocity of sound.

Although metal airscrews are at present in general use, it appears that this type becomes very heavy when applied to units of the order of 2,000 h.p., such as will be required in the near future. For this reason, blades made of resin treated and compressed wood are receiving attention, on account of the relatively low density of this material (1.35) combined with satisfactory strength. The author describes the manufacture of treated wood propellers in which the various constituent layers are of different density. The C.G. of the blade can be located in the proximity of the root, which is threaded and provided with a steel shell for location in the hub. The threads are filled with plastic material and the blade end of the shell is bevelled and fitted with a rubber insert. A photograph shows a four-bladed propeller of this type, 4.5 m. diameter and absorbing 2,000 h.p. at 1,100 r.p.m. No weights are given. In order to reduce visibility, it is stated that all propellers are now given a coat of dull green paint.

Terminal Velocity Dives. (B. Worley, Aeronautics, Vol. 3, No. 3, Oct., 1940, pp. 34-36.) (85/10 Great Britain.)

The terminal velocity of a body dropped from any altitude is reached when the air drag equals the weight. A solid dural sphere 4 feet in diameter weighs about 6,000 lb. and reaches a terminal velocity of 850 m.p.h. at 5,000 feet. A hollow sphere of the same size, with walls 1/10 in. thick weighs 75 lb. and its terminal velocity at the same altitude is only 95 m.p.h. A glider weighing 700 lb. would reach a T.V. of about 300 m.p.h. under similar conditions. Neglecting propeller drag and compressibility effects, a modern single-seat fighter weighing 6,000 lb. will have a terminal velocity of over 700 m.p.h. With the propeller

locked (*i.e.*, rotation prevented by brake) and zero incidence (blades broadside to the air) the T.V. is reduced to 425 m.p.h. If the propeller during the dive is driving the throttled engine, the T.V. will depend on the pitch setting and except for zero and 90° pitch setting, the T.V. will be greater than with the propeller locked. Although at zero pitch, the propeller is at rest, the speed of rotation will increase extremely rapidly with increase of pitch, reaching a maximum at about 10° setting. Smaller engine r.p.m. will be produced at large pitch settings, but in this range the terminal velocity is scarcely affected. The same phenomena, but in an accentuated form are produced if the engine throttle is opened up during the dive, *i.e.*, the possibility of engine damage limits the T.V. to power dives below the throttled value (in other words, the power dive cannot be as steep). If a free wheel were provided between engine and propeller, limitations of engine r.p.m. no longer arise and provided the propeller is built strong enough, a braking effect similar to that of the throttled engine case can be obtained. The disadvantage of this method lies in the fact that it may be difficult to restart the engine after a prolonged dive. The same drawback applies to the blocked propeller. As a result of all these considerations, it appears that the present method of reducing T.V. by means of air brakes attached to the wings provides the only practical solution of the problem.

(Abstractor's Note.—Most of the above is based on N.A.C.A. Technical Report No. 641.)

Static Thrust and Power Characteristics of Six Full-Scale Propellers. (E. P. Hartman and D. Biermann, N.A.C.A. Report No. 684, 1940.) (85/11 U.S.A.)

Static thrust and power measurements were made of six full-scale propellers. The propellers were mounted in front of a liquid-cooled engine nacelle and were tested at 15 different blade angles in the range from $-7\frac{1}{2}°$ to 35° at 0.75 R. The test rig was located outdoors and the tests were made under conditions of approximately zero wind velocity.

Aerofoil characteristics computed from the static test data, by the single point method developed by Lock, were considerably different from the aerofoil characteristics computed from wind tunnel test data for the same propeller and nacelle.

The tests showed a marked variation of static thrust and power coefficients with tip speed for the range of blade angles from about $7\frac{1}{2}°$ to $17\frac{1}{2}°$. A propeller with R.A.F. 6 aerofoil sections showed the greatest effect of compressibility and a propeller with N.A.C.A. 2,400-34 series sections showed the least effect. A propeller with a wide blade showed much less effect of compressibility than a similar propeller with a blade of normal width.

Effect of Exit-Slot Position and Opening on the Available Cooling Pressure for N.A.C.A. Nose-Slot Cowlings. (G. W. Stickle, I. Naiman and J. L. Crigler, N.A.C.A. Report No. 687, 1940.) (85/12 U.S.A.)

An investigation of full-scale nose-slot cowlings has been conducted in the N.A.C.A. 20-foot wind tunnel to furnish information on the pressure drop available for cooling. Engine conductances from 0 to 0.12 and exit-slot conductances from 0 to 0.30 were covered. Two basic nose shapes were tested to determine the effect of the radius of curvature of the nose contour; the nose shape with the smaller radius of curvature gave the higher pressure drop across the engine. The best axial location of the slot for low-speed operation was found to be in the region of maximum negative pressure for the basic shape for the particular operating condition. The effect of the propeller operating condition on the available cooling pressure is shown. The cooling pressure for low air speed depends markedly on the blade section near the hub. The maximum pressure drop $\Delta p/q$ obtained for the high speed condition with an engine conductance equivalent to that of a modern double-row radial engine and a propeller with good blade

sections near the hub is 1.45 and, for the take-off condition, is 3.75; for a propeller with a round blade shank, the values are 1.23 and 1.65 respectively.

Aerodynamic Characteristics of Horizontal Tail Surfaces. (A. Silverstein and S. Katzoff, N.A.C.A. Report No. 688, 1940.) (85/13 U.S.A.)

Collected data are presented on the aerodynamic characteristics of 17 horizontal tail surfaces, including several with balanced elevators and two with end plates. Curves are given for coefficients of normal force, drag, and elevator hinge moment. A limited analysis of the results has been made. The normal force coefficients are in better agreement with the lifting surface theory of Prandtl and Blenk for aerofoils of low aspect ratio than with the usual lifting line theory. Only partial agreement exists between the elevator hinge moment coefficients and those predicted by Glauert's thin aerofoil theory. Experimental results of the effect of end plates are in good agreement with theory.

Preliminary Wind Tunnel Investigation of an N.A.C.A. 23012 Aerofoil with Various Arrangements of Venetian Blind Flaps. (C. J. Wenzinger and T. A. Harris, N.A.C.A. Report No. 689, 1940.) (85/14 U.S.A.)

An investigation has been made in the N.A.C.A. 7 by 10-foot wind tunnel of a large chord N.A.C.A. 23012 aerofoil with several arrangements of venetian blind flaps to determine the aerodynamic section characteristics as affected by the over-all flap chord, the chords of the slats used to form the flap, the slat spacing, the number of slats, and the position of the flap with respect to the wing. Complete section data are given in the form of graphs for all the combinations tested.

The optimum arrangement of the venetian blind flap was a combination in which the flap was located near the wing trailing edge. These arrangements of the venetian blind flap were superior to any flaps previously tested for producing lift and giving low drag coefficients at high lift coefficients. The wing with this flap, however, had very large pitching moment coefficients. When operated as split flaps, the venetian blind flaps were inferior to the simple split flap in producing lift.

Longitudinal Stability and Control, with Special Reference to Slipstream Effects. (S. Katzoff, N.A.C.A. Report No. 690, 1940.) (85/15 U.S.A.)

Data obtained in the N.A.C.A. full-scale wind tunnel concerning the effects of interference and of propeller operation on longitudinal stability and control have been studied. The data include pitching moments for various power conditions for aeroplanes with tails removed and with tails set at various stabiliser and elevator angles. A number of surveys of the dynamic pressure and the flow direction in the region of the horizontal tail surface are also included. Results are given for eight aeroplanes, including a model of a four-engine aeroplane tested both as a tractor and as a pusher and a model of a two-engine pusher. The effects are shown of propeller operation on the downwash angles and the dynamic pressures at the tail and on the pitching moment contribution of the propeller and the wing.

The rate of increase of effective downwash angle ϵ_{eff} with angle of attack α, $d\epsilon_{eff}/d\alpha$, was considerably increased by propeller operation in the case of the gull wing and the parasol wing monoplanes, only slightly increased in the case of the four-engine pusher, and increased hardly at all in the case of the two-engine pusher. The downwash angle itself, however, was increased by propeller operation over the entire angle-of-attack range in the case of the pusher models.

The slipstreams at the tail locations were well defined, especially with the pusher models, and had approximately the same diameters as the propellers. In the case of the four-engine pusher, there appeared to be a definite shearing of the slipstream due to the trailing vortex sheet.

The largest observed variation in downwash angle across the elevator hinge line was 15° for the case of the two-engine pusher model, T'_c having a value of 0.435. The values of q/q_0 across the elevator hinge line for the same case varied between 1.0 and 3.2.

Free-Spinning Wind Tunnel Tests of a Low Wing Monoplane with Systematic Changes in Wings and Tails v. Effect of Aeroplane Relative Density. (O. Seidman and A. I. Neihouse, N.A.C.A. Report No. 691, 1940.) (85/16 U.S.A.)

The reported tests are a continuation of an N.A.C.A. investigation being made in the free-spinning wind tunnel to determine the effects of independent variations in load distribution, wing and tail arrangement, and control disposition on the spin characteristics of aeroplanes.

The standard series of tests was repeated to determine the effect of aeroplane relative density. Tests were made at values of the relative density parameter of 6.8, 8.4 (basic), and 12.0; and the results were analysed. The tested variations in the relative density parameter may be considered either as variations in the wing loading of an aeroplane spun at a given altitude, with the radii of gyration kept constant, or as a variation of the altitude at which the spin takes place for a given aeroplane. The lower values of the relative density parameter correspond to the lower wing loadings or to the lower altitudes of the spin.

For all tail and wing arrangements, the lower values of the relative density parameter gave faster recoveries from steeper spins and the higher values gave slower recoveries from flatter spins than for the basic loading condition. In general, as the relative density parameter decreased, the rate of vertical descent decreased, the spin coefficient $\Omega b/2V$ increased, and the sideslip became more outward. The importance of aeroplane relative density, wing arrangement, and control manipulation increased as the effectiveness of the tail unit decreased.

Steam Turbine Blading (with Discussion). (R. C. Allen, Trans. A.S.M.E., Vol. 62, No. 8, Nov., 1940, pp. 689-710.) (85-17 U.S.A.)

This paper reviews the blading design practice associated with modern high pressure high temperature steam turbines. The design problems encountered in the development of partial admission impulse blading for topping units are described, as well as the current engineering practice employed in the manufacture of such blading. The stress analysis used in the construction of full admission blading is reviewed. The design procedure adopted for high tip speed last row blading and the natural limits in capacity imposed on 3,600 r.p.m. turbine construction are also discussed. Materials for turbine blading are considered, as well as the metallurgical problems associated with the fabrication and welding of the high grade alloy steels now available.

Exhaust Pipe Pressure Waves. (L. J. Kastner, Engineering, Vol. 150, No. 3,901, 18/10/40, pp. 301-303.) (85/18 Great Britain.)

It has been known for some time that in certain circumstances the discharge of the exhaust gases from an engine cylinder may give rise to a vacuum which can be employed for improving the scavenge of the engine. Until recently the general opinion appears to have been that attempts to employ this vacuum were unlikely to prove successful in practice; this view was possibly based on an insufficient understanding of the phenomena involved.

It appears that two distinct phenomena are responsible for this vacuum; firstly, a sufficiently sudden discharge from the cylinder itself may give rise to a transitory fall of pressure below atmospheric and, secondly, a periodic wave may be formed in the engine exhaust pipe, fluctuating between positive and negative values of pressure. In the former case, the magnitude of the depression will be controlled to a certain extent by the ratio of the area of the port to the cross

sectional area of the cylinder, and also by the rapidity with which the port is opened. In the latter case, the amplitude of the depression will depend on a number of factors, the most important being the dimensions of the exhaust pipe itself.

The present article is confined entirely to a discussion of the production of pressure waves in the engine exhaust system, and no attempt is made to analyse conditions in the cylinder due to the sudden discharge of gases therefrom.

In a brief article it is clearly impossible to do more than indicate the nature of exhaust pipe waves, to give some idea of the factors governing wave form and frequency, and to suggest how such waves may be usefully employed. A calculation of the absolute amplitude of the wave at any instant is difficult and laborious, and the results obtained do not repay the trouble involved, since all that is required in practice is a knowledge of the approximate wave form and frequency in relation to the valve timing.

Infinitely Variable Mechanical Gears. (F. G. Altmann, Z.V.D.I., Vol. 84, No. 20, 18/5/40, pp. 333-338.) (85/19 Germany.)

Infinitely variable gears may be of the friction or oscillating linkage type. In the latter case speed variation is obtained by altering the effective amplitude of oscillation of the link, the conversion to rotary motion being produced by the introduction of a ratchet or self-blocking free wheel. The former does not enable stepless variation in speed of rotation, since the number of possible speed ratios depends on the number of teeth utilised per power stroke. The self-blocking free wheel resembles a normal roller bearing, except that driving elements of suitable shape are inserted between the rollers. These elements are so shaped that the effective linkage angle with the diameter of the circular assembly is less than the angle of friction, external contact being assured by means of a suitable spring. The incorporation of such a device enables the construction of truly infinitely variable gears which, moreover, operate without noise.

The double energy conversion in mechanical gears of this type introduces special design problems which are discussed and diagrams are given which enable the velocity and force range to be estimated. Commercial forms of such gears, such as the Greenig-Galloway, Gyrel and Morse are described. It appears that the very high standard of manufacture required to ensure efficient operation will present difficulties.

Piston Deposits, Ring Sticking, Varnishing and Ring Clogging (Condensed from J. Inst. Petrol.). (W. A. Gruse and C. J. Livingstone, Engineer, Vol. 170, No. 4,429, 29/11/40, pp. 352-3.) (85/20 Great Britain.)

Engine varnishing, ring sticking, and oil ring clogging are more or less closely related. Oxidation of the oil, chiefly in the crank case, to unstable products, followed by the decomposing of these products at hot points in the engine, play an important part in all three.

It is recognised that increased outputs necessarily involve higher piston and cylinder wall temperatures. However, it does not seem necessary that crank case temperatures must also be higher. Since the effect of increased temperature on rate of oxidation is enormous—a 20 deg. Fah. rise means approximately a doubling of the oxidation rate—every decrease in crank case temperature means a real improvement. While it is true that the oil is exposed to more severe conditions for short time periods, it must be remembered that the bulk of the oil spends most of its time at the crank case temperature. It seems reasonable, therefore, to hope that engine designers can arrange to keep crank case oil temperatures low. They will thus take an unnecessary load off the oil, leaving it in better condition to carry the necessary load it encounters on the piston, cylinder walls, and bearing surfaces.

Performance of Modern Aircraft Diesels (with Discussion). (P. H. Wilkinson, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 474-81.) (85-21 U.S.A.)

A definite future exists for air-cooled four-stroke aircraft Diesel engines in the 400 to 600 h.p. class; the aircraft Diesel is at least on a basis of parity with the gasoline aircraft engine in the 1,000 h.p. water-cooled and liquid-cooled high performance class, and since the Diesel can be conveniently fitted with a turbo supercharger, there are definite advantages to be derived from the use of a two-stroke Diesel of proved worth.

The author last year visited Diesel aircraft centres in France, Germany, England, and the United States.

In reviewing the advantages of Diesel aircraft engines, he groups them as, economic advantages such as reduced fire hazard, low fuel operating costs, and large pay load and flight range possibilities; and mechanical advantages, such as reliability and efficiency.

Correlation of Cooling Data from an Air-Cooled Cylinder and Several Multi-Cylinder Engines. (B. Pinkel and H. H. Ellerbrock, N.A.C.A. Report No. 683, 1940.) (85/22 U.S.A.)

The theory of engine cylinder cooling developed in a previous report was further substantiated by data obtained on a cylinder from a Wright R-1820-G engine. Equations are presented for the average head and barrel temperatures of this cylinder as functions of the engine and the cooling conditions. These equations are utilised to calculate the variation in cylinder temperature with altitude for level flight and climb. A method is presented for correlating average head and barrel temperatures and temperatures at individual points on the head and the barrel obtained on the test stand and in flight. The method is applied to the correlation and the comparison of data obtained on a number of service engines.

When the cooling pressure drop was suddenly increased and also when the throttle was suddenly opened, a time duration of approximately four minutes was required for the temperature rise to equal 90 per cent. of the total rise to equilibrium temperature.

Hydrogenation of Petroleum. (E. V. Murphree, C. L. Brown, E. J. Gohr, Ind. and Eng. Chem. (Industrial Ed.), Vol. 32, No. 9, September, 1940, pp. 1203-1212.) (85/23 U.S.A.)

The present status of high pressure hydrogenation of petroleum is discussed as to theory and commercial application. Particular reference is made to the production of aviation gasoline, motor fuel, aviation blending agents, and Diesel fuel, and the conversion of heavy asphaltic fractions. Yields and inspection data on these operations are included. Economics are discussed, and it is shown that for a 30 cent spread between crude and fuel oil price, hydrogenation in competition with thermal cracking for production of motor fuel will show a 20 per cent. return on the added investment for hydrogenation.

Thickness of a Liquid Film Adhering to a Surface Slowly Withdrawn from the Liquid. (F. C. Morey, Bur. Stan. J. Res., Vol. 25, No. 3, Sept., 1940, pp. 385-93.) (85/24 U.S.A.)

When a solid body is immersed in a bath of liquid and withdrawn, a film of the liquid adheres to the solid surface and gradually drains back into the bath when the motion ceases. The relationship existing between the average film thickness, the speed of withdrawal, and the kinematic viscosity of the liquid is the subject dealt with in this paper.

According to the generally accepted theory the film thickness varies with the square root of the product of the speed and the kinematic viscosity. It was

noticed that corrections based on this relationship and used in the calibration of a gas measuring standard were not satisfactory. Therefore an experimental apparatus was designed to test the theory. Analysis of the data revealed that within the range of speeds used the theory does not correctly predict the film thickness, and an empirical equation of the form

$$t = k\,(\nu s)^n$$

was employed, in which t is the average film thickness, ν is the kinematic viscosity of the liquid, s is the speed of withdrawal of the surface, k and n are quantities varying slightly with the liquid used. The approximate values of k and n found by experiment are 0.015 and 0.63 respectively.

Nine liquids were tested, including mineral, vegetable, and animal oils, and synthetic organic compounds of oily nature.

Measurement of Blade Temperature of a Gas Turbine Under Load. (H. H. Berg, Z.V.D.I., Vol. 84, No. 19, 11/5/40, pp. 329-330.) (85/25 Germany.)

The D.V.L. have carried out temperature measurements on the rotors of gas turbines, making use of a special radiation pyrometer. The radiation is concentrated by means of a concave mirror on a Moll thermopyle. The corrosive nature of the exhaust gas gave troubles at first, which were finally overcome by using a special Rhodium mirror and ventilating the box housing with an air jet. Apart from only giving mean values, this method suffers from the defect that the instrument can only be focussed on the trailing edge of the blade. For this reason, complementary tests with thermocouples inserted at various points on the rotor were carried out. This necessitated the provision of rubbing contacts which presented considerable difficulties in view of the high speed of rotation ($\sim$ 25,000 r.p.m.). A type of disk commutator utilising composite copper carbon bushes was finally evolved, in which the bushes are only held in contact for a short time. The heat generated at this point is automatically compensated as far as the temperature measurement is concerned by a suitable arrangement of the electric circuit.

Metal Electric Strain Gauge. (Sci. Am., Vol. 163, No. 5, Nov., 1940, p. 265.) (85/26 U.S.A.)

Stress and stress distribution in such structures as the complicated members of aeroplanes, automobiles, railroad equipment, and bridges may now be determined and analysed by a new strain gauge. This device makes use of the fact that strain changes the electrical resistance of metallic conductors. It combines the accuracy of the testing laboratory with simplicity, convenience, and reliability. It is simply cemented to the member to be studied, has no clamps, no moving parts, no inertia distortion, and no hysteresis. Once in place, a strain gauge may be left permanently installed for months during which a complete study of the part on which it is attached may be made.

The SR-4 metalectric strain gauge is simply a small grid of specially selected metallic conductors; its overall dimensions are $\frac{3}{4}$ by $1\frac{3}{8}$ by $\frac{1}{4}$ inches. It may, therefore, be installed in places inaccessible to other forms of stress analysers.

This new gauge is particularly suited to machinery operating at high speeds because it has no detectable inertia effects and has been tested at frequencies of over 30,000 cycles per second, with no indication as to any upper limit to the response.

Simultaneous Recorder for Engine r.p.m. and Boost Pressure—Type Peravia R.D. 239. (Flugwehr und Technik, Vol. 2, No. 1, Jan., 1940, pp. 20-21.) (85/27 Switzerland.)

Boost and atmospheric pressure are measured by means of aneroid capsules which are compensated for temperature changes. The readings are continuously

recorded on a moving strip of paper with a wax surface, the stylos being fitted with hard steel points. No ink is thus required. The movement of the paper is by clockwork which is rewound by a flexible shaft attached to the engine. The same shaft also drives a visible rev. counter which is incorporated in the instrument. This counter works on the integrating principle and its readings are transferred to the paper at regular intervals by means of a third stylo. The clockwork mechanism driving the band also provides the latter with time marks at regular intervals.

No weights and sizes are given.

Stress Strain Analysis. (Machinist, 21/9/40, pp. 322-323.) (85/28 Great Britain.)

Qualitative pictures of areas of strains and their directions can be seen in various types of brittle coating, and research work has recently been directed to the production of lacquers for coating and to methods of calibration, which might enable accurate quantitative measurements of strains and stresses in the coated body. The technique of applying the coating and carrying out a quantitative calibration is described. Since the lacquer is not affected by compression strains, measurement of compression stresses is obtained by placing the tested material under full load, applying the coating, and releasing the load, so placing the coating under equal tensile strains.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Metrovick Resistance Welding Machines. (Dorrat, M.-V. Gazette, Sept., 1940, pp. 52-62.) (85/29 Great Britain.)

Some of the special resistance welding machines devised by M.-V. are described. Spot welding machines range from light duty bench type welders, where pressure and length of weld are controlled by the operator, to the heavy duty type, with which infinite variation of welding heat may be obtained by means of " phase control " incorporated in the ignition control system, and also by electrically operated air valves, a definite pressure cycle may be applied during welding. The M.-V. portable spot welding machine and the aircraft type spot welding machine are also described. Butt welding machines, where correct balance between pressures, " push-ups " and welding currents is essential, and seam welding machines are briefly reviewed.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Electro-Deposition of Alloys. (Metallurgia, Oct., 1940, pp. 184-5.) (85/30 Great Britain.)

Progress in this field during the last ten years is briefly reviewed and some important developments are discussed. The requirements of alloy plating on a commercial scale, and factors influencing deposition are enumerated. Recent research is reported to have shown that the *pH*, the nature of addition agents or salts, and metal impurities in the bath are of great importance in determining the character of the plate. Problems associated with plating with many different alloys are discussed, and certain special applications of alloy plating are described, electro-deposited copper and graphite bearings being noted particularly.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Bearing Metals. (M. Melhuish, Autom. Eng., Vol. 30, No. 402, Oct., 1940, pp. 303-6.) (85/31 U.S.A.)

The bearing alloys used at the present time may be divided into eight groups :—

(1) Tin base alloys, in which the matrix consists of practically pure tin, containing compounds of tin and antimony, and tin and copper.

(2) Lead base alloys, whose base is chiefly lead or lead and tin, containing a compound of tin and antimony.

(3) Alloys consisting of a solid solution of copper and tin (or copper and zinc), and containing compounds of copper and tin and phosphorus, *i.e.*, bronzes and phosphor bronzes.

(4) Alloys consisting of a solid solution of copper and tin (sometimes containing zinc, nickel, etc.), and containing free lead, *i.e.*, the lead bronzes.

(5) Zinc base: Zinc base metals generally contain anything over 70 per cent. zinc hardened with copper.

(6) Aluminium alloys whose base is chiefly aluminium with the addition of silicon, copper, manganese, tin and titanium as hardening agents.

(7) Powdered metals: These can be made of many mixtures and are generally bonded under pressure and sintered. Some are impregnated with oil for use as self-oiling bearings.

(8) Plastic bearings: Usually made from Phenol Formaldehyde or Urea-Formaldehyde types of synthetic resins.

Although white metal lined bearings will stand up to heavy duty in Diesel engines provided the bearing area is designed to reduce the load to a reasonable figure, it would seem that engine builders are still seeking a material that has a high fatigue strength, and high resistance to the heavy and pounding loads it is called upon to carry while retaining the advantages of a high grade tin base babbitt. This is apparent from the fact that alternative bearing metals are being used with varying success. Whether it is possible to evolve a metal having the characteristics mentioned above is a problem which must be left to the metallurgists.

Mechanical and Physical Properties of High Duty and Alloy Cast Irons. (J. W. Donaldson, Metal Treatment, Summer, 1940, pp. 51-57, 61.) (85/32 Great Britain.)

Properties of cast iron such as resistance to corrosion, wear and heat, and machinability, which are not intrinsic properties, depend, with the exception of the last, on the conditions which the material has to withstand in service and are largely related to composition and structure. Austenitic irons, such as Nicrosilal and Ni-resist, have a much better resistance to wear, corrosion, and heat than irons with a pearlitic structure, but are brittle and lack the strength of pearlitic irons. Pearlitic cast irons show the best wear resistance when they contain small, well distributed graphite, and when the phosphide eutectic is also well distributed. They have little resistance to corrosion, however, and in this respect are similar to carbon and low alloy steels. Special irons to resist chemical corrosion, in addition to the austenitic irons, are high silicon irons containing 15 per cent. silicon and irons containing 10 per cent. chromium. The latter iron has also a good heat resistance, a property which is still more fully developed with 30 per cent. chromium, giving a strong, tough, machinable iron. An iron containing aluminium and chromium has also been successfully developed recently for heat resistance.

Another property of cast iron which has been brought into prominence in recent years is its damping capacity or capacity for dissipating vibrational energy. This property, which is developed in materials showing a large amount of plastic deformation and having a low modulus of elasticity, both of which cast iron possesses, absorbs stresses developed under working conditions and which, if they become superimposed, proved dangerous. In this respect it renders cast iron suitable for the manufacture of cast crankshaft.

SUMMARY OF STATIC, IMPACT, HARDNESS, AND FATIGUE TESTS ON HIGH DUTY AND ALLOY CAST IRONS (GOUGH AND POLLARD).

Material.			Copper-Chromium Iron.	Inoculated Iron.	Chrome-Molybdenum Iron.	Nickel-Chromium Iron.
Tensile limit of proportionality, tons per sq. in.			15·5	2·5	2·5	2·2
Ultimate tensile strength, tons per sq. in. ...			32·3	23·3	20·8	18·8
Modulus of elasticity, lb. per sq. in. × 10^6 ...			26·8	21·7	20·1	18·7
Brinell hardness			260·0	245·0	280·0	265·0
Torsional limit of proportionality, tons per sq. in.			15·6	4·3	2·7	2·7
Torsional modulus of rupture, tons per sq. in.			38·6	31·9	32·7	21·1
Total twist at fracture ($L/D=8\frac{1}{3}$), degrees ...			96·0	82·0	53·0	16·0
Modulus of rigidity, lb. per sq. in. × 10^6 ...			11·4	8·6	8·6	7·1
Izod, notch bar, ft./lb.			1·2	1·5	0·8	0·4
Wohler fatigue limit, tons per sq. in.... ...			±21 to ±19	±12·9	±9·4	±8·9
Alternating torsional fatigue limit, tons per sq. in.			±14·7 to ±13·9	±9·7	±8·4	±7·1
Fatigue resistance as determined using combined stress machine	Cycles of reversed bending stresses	Fatigue limit, tons per sq. in.	±18·2	±12·9	±10·8	±10·6
		Endurance ratio	0·564	0·554	0·519	0·564
	Cycles of reversed shearing stresses	Fatigue limit, tons per sq. in.	±14·4	±11·4	±10·9	±8·9
		Endurance ratio	0·446	0·489	0·524	0·473

New Type of Safety Glass. (British Plastics, Vol. 12, No. 137, Oct., 1940, p. 163.) (85/33 Germany.)

The I.G. Farbenindustrie of Germany has developed a new type of safety glass which leaves no splinters and provides remarkable adherence between laminations. Two thin sheets of glass are held together by an interlay of plastic material. This plastic is produced by polymerising 16 molecules of vinyl acetate and one molecule of dimethyl maleate, which is then saponified by acetylation with butylaldehyde. To 100 parts of the resultant substance are added 66 parts of isoheptylic ether salt of diglycolic acid, and the whole is plasticised with 11 parts of methoxy-butanol. This is then heated to 80°C. and thoroughly mixed together. It can then be rolled into a sheet which is pressed between two thin sheets of ordinary glass and heated to 120°C. The whole is finally cooled under pressure. Adherence between the glass and the plastic is said to be very remarkable.

Improvements in Cutting Oils. (A. G. Arend, Chem. and Ind., Vol. 59, No. 46, 16/11/40, pp. 771-772.) (85/34 Great Britain.)

Cutting oils are expected to minimise the power consumed, provide lubrication between the tool and the work, dissipate heat and cool both metal surfaces, increase the life of the tool, flush away turnings and chips, and prevent corrosion.

For reliable film strength, lard oils, mineral-lard oil blends, and sulphurised oils predominate, but lard oil has a good record for most metals for purely cutting purposes. Cotton seed oil, although it has certain chemical disadvantages, is considered the best representative of the vegetable oils, whereas what are

known as " straight " mineral oils very largely owe their popularity to the economy gained, rather than to any special qualities.

To-day, alkaline solutions are only to be seen in use in certain grinding operations to assist in cooling, and laying the dust, rather than in any cutting or lubricating capacity.

The introduction of sulphur to cutting oils produced a marked change, as almost any class of steels or alloy steels could be machined at any desired speed, and thus obviated the need for making frequent changes of the liquid medium. When properly compounded, the property of oiliness is sometimes even greater than that of pure lard oil, and the increased film strength is thought to be due to the affinity which sulphur in combination with oil has for metals.

After making analysis of a number of sulphurised oils it was found that the total sulphur content seldom exceeded 2 per cent., but with others of a much richer type, a certain sulphurous corrosion appeared on the metal, which with the cutting edges of fine tools is apt to be serious.

One method of testing whether one type of cutting oil is better than another is to take observations of the kind of chips removed by the tool, and lengthy curling chips which bear heavily on the tool suggest the need for a heavily compounded sulphurised oil, while chips which break off hard indicate that a plain compounded oil, or at least lightly sulphurised oil will suit the purpose best. Successful production of cutting oils very largely depends upon co-operation between the engineer and the oil manufacturing firm, so that all features of working at the greatest speeds will be given every consideration at the present time.

The Tinning of Piston Rings. (Engineering, Vol. 150, No. 3,906, 22/11/40, p. 410.) (85/35 Great Britain.)

The piston rings are ground accurately to size, making an allowance for the thickness of the tin deposit which is subsequently applied. As a result of the grinding operation, the periphery of the ring has a surface composed mainly of disturbed and flowed material, which would be liable to become detached and cause wear in service. In the next operation any grease present on the rings is removed in a hot alkaline bath, and they are then etched in an acid bath. The etching treatment frees the surface from loosely adherent and smeared material left by the grinding operation and leaves a pitted surface consisting of small hollows or depressions. The rings are then washed thoroughly and given a coating of 0.0005 in. (0.012 mm.) of pure tin in an electro-tinning bath of the alkaline-stannate type. After final washing and drying the rings are ready for use.

It is stated that the pitted structure of the tinned surface possesses a number of advantages. In the first place, it assists in retaining the lubricating oil on the ring during the formation of the Beilby layer. Furthermore, the coating of tin is sufficiently plastic to flow at the points of greatest pressure and thus prevents scoring while the surfaces are running in and the Beilby layer is being formed. It is emphasised that the combination of a hard network of iron phosphide, present on the surface, with plastic pure tin resembles ordinary bearing metals in which relatively hard particles are embedded in a softer matrix.

Modern Aircraft Materials and Their Testing. (K. R. Jackman, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 461-73, 496.) (85/36 U.S.A.)

From a quick glance at some of the newer aircraft materials and test procedures, we find that the high tensile aluminium alloys still hold the structural field, although crowded a little by some of the magnesium alloys. The alloys of beryllium hold only minor structural promise, but the pure beryllium metal

may have a future for armour plate in planes. Chrome-molybdenum steel maintains its favoured position, but it has lost some ground to the stainless steels, especially of the heat treatable " M.286 " variety. Plastic and wood and plastic construction probably will not immediately replace light metal construction. Therma-plastic windows with their weight savings, are edging out those of laminated glass, but should be tested carefully for pressurised cabin uses.

The pre-stretching of aluminium alloy stiffeners offers a method of gaining strength at no cost in weight or price. Pre-compressing, theoretically of great promise, runs into practical shop difficulties on application.

The electric resistance strain gauge of the Celstrain or Baldwin-Southwark type promises to add new impetus to practical full-scale testing and research at one-tenth of the instrumentation cost of former remote recording extensometers.

Hot Strength of Various Aluminium Alloys. (A. V. Zeerleder, Inter. Avia., No. 732, 21/10/40, pp. 1-4.) (85/37 Switzerland.)

Wire specimens of the following metals and alloys have been exposed to even temperatures ranging up to a whole year and tested as to limit of stretching strain, strength and expansion after periods of 7, 15, 30, 60, 90, 180, and 360 days. The values shown in the table that follows give the effect of this long period of heating on the strength properties.

VALUES OF THE LIMITS OF STRETCHING STRAIN OF DIFFERENT WIRE SPECIMENS AFTER ONE YEAR'S CONTINUOUS HEATING AT TEMPERATURES OF 20, 50, 75, 100 AND 160 DEG. C.

Specimen.	Wire ϕ	Continuous Heating at 20°C.	50°C.	75°C.	100°C.	160°C.
Pure Al 99.5	2.4 mm.	13.6	13.2	11.0	13.1	7.4
Anticorodal B	3.0 mm.	21.5	24.2	25.9	25.3	8.4
Avional D	2.8 mm.	29.2	29.4	32.6	39.1	15.4
Copper	2.5 mm.	37.7	37.0	26.4	21.0	10.7
Nickel	2.0 mm.	76.7	78.0	80.5	77.3	74.8
Steel wire No. 1 (hard drawn) ...	2.0 mm.	78.4	79.6	76.3	81.2	74.0
Steel wire No. 2 (zinc plated) ...	2.0 mm.	112.0	116.8	109.0	119.6	112.5

VALUES OF BREAKING-STRAIN RESISTANCE.

Specimen.	Wire ϕ	Continuous Heating at 20°C.	50°C.	75°C.	100°C.	160°C.
Pure Al 99.5	2.4 mm.	16.5	16.2	16.3	14.6	10.8
Anticorodal B	3.0 mm.	32.9	33.9	35.0	34.7	14.8
Avional D	2.8 mm.	48.0	47.9	50.6	51.6	26.9
Copper	2.5 mm.	44.2	42.6	33.7	29.4	26.1
Nickel	2.0 mm.	89.0	88.1	88.8	91.4	93.3
Steel wire No. 1 (hard drawn) ...	2.0 mm.	93.6	92.0	89.6	92.3	88.9
Steel wire No. 2 (zinc plated) ...	2.0 mm.	147.1	147.0	143.0	146.7	146.8

VALUES OF EXPANSION.

Specimen.	Wire ϕ	Continuous Heating at 20°C.	50°C.	75°C.	100°C.	160°C.
Pure Al 99.5	2.4 mm.	1.5	1.8	1.2	1.5	18.0
Anticorodal B	3.0 mm.	13.2	13.2	11.6	9.2	13.2
Avional D	2.8 mm.	16.4	16.7	13.9	8.8	7.5
Copper	2.5 mm.	1.9	2.4	10.5	19.6	34.7
Nickel	2.0 mm.	1.5	1.4	1.8	3.0	5.7
Steel wire No. 1 (hard drawn) ...	2.0 mm.	1.5	1.6	1.3	1.3	1.6
Steel wire No. 2 (zinc plated) ...	2.0 mm.	5.4	5.7	5.3	5.6	5.8

During this study, the specimen wires were always tested at a temperature of 20 deg. C. after cooling down, as merely the weakening resulting from continuous heating was to be determined while the loss of strength in tests at raised temperatures was known from the investigations conducted with the material in the incompletely stabilised condition.

Particularly in the aircraft industry which always counts on comparatively short actual periods of operation a testing period extending over a whole year, which corresponds to 8,600 hours of operation of an aircraft, may surely be considered as adequate.

The admissible maximum limit of heating of aluminium alloys in the aircraft industry thus may safely be put at 130 deg. C.

Plating Wire Tips for Electrical Instruments. (Downie, Electrical Engineer, 29/11/40, pp. 88-9.) (85/38 Great Britain.)

In view of the economic advantage of using plated rather than solid tips for electrical contacts, there has been considerable research directed to the manufacture of such contacts. The present article describes methods of testing deposit thickness, preparation of the wire for plating, and the arrangement of the electrolysis bath. Every effort is made to avoid wastage, in view of the cost of the platinum-iridium or platinum-rhodium used.

(Abstract supplied by Research Dept., Metropolitan-Vickers.)

"Tocco" Process for Hardening Steel Surfaces. (Engineering, 29/11/40, pp. 426-7.) (85/39 Great Britain.)

A process has been developed in the U.S.A. whereby steel surfaces can be hardened locally to increase resistance to wear. Heating of the part is effected in a few seconds by high frequency induction, and quenching done by means of high pressure water jets. The process and the factors which influence it are discussed and data given relating to the increased hardness of the treated surface.

(Abstract supplied by Research Dept., Metropolitan-Vickers.)

An Improved Radio Sonde and its Performance. (H. Diamond, W. S. Hinman, F. W. Dunmore and E. G. Lapham, Bur. Stan. J. Res., Vol. 25, No. 3, Sept., 1940, pp. 327-07.) (85/40 U.S.A.)

The radio sonde (radiometeorograph), described in Research Paper RP 1,082, has emerged from the laboratory and been put into daily service in a widespread network of stations by the Government aerological services. The present paper describes improvements in component elements of the radio sonde system and discusses performance. Actual performance in service is stressed. The major improvement introduced is in the element for measuring relative humidity. Laboratory and flight data on the accuracy of measurement with this element at temperatures down to $-60°C$. are presented. The improved radio sonde is shown to be capable of measuring barometric pressure to an accuracy of 5 millibars, temperature to an accuracy of 0.75 degrees Centigrade, and relative humidity to an accuracy of 5 per cent.

Car Riding Comfort and Cushions. (W. E. Lay and L. C. Fisher, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 482-96.) (85/41 U.S.A.)

Methods used in studying the relations between the automobile seat cushion and its function in transporting passengers with greater comfort and less fatigue are described.

A piece of apparatus called the Universal Test Seat was constructed, whose dimensions were completely adjustable with arrangements to vary the distribution of the supporting pressure in any manner which seemed most comfortable to the passenger.

The following mechanical objectives should be attained by the cushion:—

1. To support the passenger over a large area to get the smallest unit pressure on the flesh;
2. To avoid variations in pressure from point to point over the supported area except those variations dictated by actual variations in the body of the passenger. (To obtain the surface contour and pressure distribution on the loaded cushion that is considered by the average passenger to be the most comfortable.)

By extending their analysis of the conditions required for static comfort, the authors believe that the objectives to be attained for dynamic comfort are:—

1. To avoid large changes in pressure or forces acting on the body of the passenger with respect to time;
2. Especially to avoid high rates of change, with respect to time, of either the values or direction of pressures or forces acting on the human body.

Ultra Short Wave Transmission over a 39-Mile "Optical" Path. (C. R. Englund, A. B. Crawford and W. W. Mumford, Proc. Inst. Rad. Engs., Vol. 28, No. 8, Aug., 1940, pp. 360-9.) (85/42 U.S.A.)

Continuous records of ultra short wave transmission on wave lengths of 2 and 4 meters, over a good "optical" path, have shown variations in the received signal strength. These variations can be explained as being due to wave interference; an interference which varies with the changes in the composition of the troposphere.

Some of the variations are due to changes in the dielectric constant gradient of the atmosphere near the earth. Other variations are explicable in terms of reflections from the discontinuities at the boundaries of different air masses. The diurnal and annual meteorological factors which affect the transmission are discussed.

Psycho-Medical Investigations on Flying Accidents. (H. Meier Muller, Flugwehr und Technik, Vol. 2, No. 1, Jan., 1940, pp. 12-14, and No. 2, February, 1940, pp. 40-42.) (85/43 Switzerland.)

The accidents reviewed by the author are those attributable to the failure of the pilot as distinct from those due to failure of the aircraft structure.

The failure of the pilot due to purely medical reasons is rare. Nevertheless, cases of sudden giddiness due to nicotine poisoning, after effects of flu and other diseases, as well as more dangerous collapse due to the breaking of internal abscesses have occurred. Here only a strict medical history of the pilot can be of help. In several instances pilots are known (from observation or conversation subsequently reported) to have undertaken flights for reasons of professional pride although not feeling fit. This should be severely discouraged.

Indirect medical failure due to faulty oxygen supply or exhaust gas poisoning also come under this category. Here active co-operation with experienced doctors in the early stages of the installation is often wanting.

By far the greatest number of accidents attributable to the failure of the pilot are classed under the general heading of "errors of judgment." These errors are in most cases psychological. It is most important that the pilot should have confidence, not only in the machine but also in himself. Every accident must

be investigated and a reason must be given to the pilot. Too little attention is paid to the strain accompanying flying under dangerous conditions. Circumstances may arise, when the pilot is literally staring death in the face for several minutes. Although he may, and often does, get out of these situations alive and apparently none the worse, there can be no doubt that such experiences, although repressed into the subconscious, may have serious and unexpected subsequent effects on the nervous condition. Adequate rest and careful supervision will become more and more necessary.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.), Ministry of Aircraft Production, and copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

THEORY AND PRACTICE OF WARFARE.

TRANSLATION NUMBER AND AUTHOR.	TITLE AND REFERENCE.
1118 Hemardinquer, P. ...	*New Electrical and Radio-Electrical Methods for Spotting Aircraft.* (La Science et la Vie, Vol. 57, No. 276, June, 1940, pp. 603-611.)
1119 Hollbach, O. ...	*German Aircraft Construction—Export Handbook of the Aircraft Industry. Section IX A, Aircraft Armament and Sights.* (Deutscher Flugzeugbau—Handbuch der Luftfahrttechnik, 1939.)
1120 Hollbach, O. ...	*German Aircraft Construction—Export Handbook of the Aircraft Industry. Section IX B, Bombs and Bomb Release Gear for Aircraft.* (Deutscher Flugzeugbau—Handbuch der Luftfahrttechnik, 1939.)
1121 Hollbach, O. ...	*German Aircraft Construction—Export Handbook of the Aircraft Industry. Section IX D, Bomb Release Mechanism.* (Deutscher Flugzeugbau—Handbuch der Luftfahrttechnik, 1939.)
1122 Hollbach, O. ...	*German Aircraft Construction—Export Handbook of the Aircraft Industry. Section IX F, Mechanical and Optical Training Apparatus.* (Deutscher Flugzeugbau—Handbuch der Luftfahrttechnik, 1939.)
1125 Cremona, C. ...	*A Graphical Method for the Determination of the Centre of Balance for the Stabilisation of Aerial Bombs.* (L'Aerotecnica, Vol. 20, No. 1, Jan., 1940, pp. 11-19.)
1126 Palchikov, A. S. ...	*On the Calculation of the Quantity of Bombs Required for Bombing Various Targets.* (Air Fleet News, U.S.S.R., Vol. 23, No. 7, July, 1940, pp. 27-31) (condensed version.)

Translation Number and Author.		Title and Reference.
1127	Schneider, W. ...	*Investigation into the Determination of Pressures Inside Propulsive Air Waves due to Detonation and Gunfire.* (Z.G.S.S., Vol. 34, No. 8, Aug., 1939, pp. 230-4; No. 9, Sept., 1939, pp. 263-6; No. 10, Oct., 1939, pp. 284-6; No. 11, Nov., 1939, pp. 304-6; No. 12, Dec., 1939, pp. 329-31.) (War Office Translation Nos. M.I.1.T. 8,782 and 9,327.)

Miscellaneous.

1123	Rubin, B. I. ...	*Electric Supply Systems for Aircraft.* ("Electricity," U.S.S.R., Vol. 61, No. 1, Jan., 1940, pp. 9-15.)
1124	Woehl, W.	*Some New Muzzle Velocity Measuring Instruments Using a Short Measurement Base.* (Beiträge zur Ballistik und Technischen Physik, 1938, pp. 117-127.) (R.D. Translation No. 908.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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(*Prepared by R.T.P.*)

No. 86. JANUARY, 1941.

On the Subsonic Flow of a Compressible Fluid Past an Elliptic Cylinder. (I. Imai and T. Aihara, Aer. Res. Inst., Tokyo, Vol. 15, No. 194, Aug., 1940.) (86/1 Japan.)

In this paper a new method of treating the two-dimensional subsonic irrotational flow of compressible fluids is given, which consists essentially of making use of conjugate complex variables. In illustration of the method the flow past an elliptic cylinder in an arbitrary orientation with any circulation is considered, and the expression for the velocity potential correct to the order of M^2 is obtained, without recourse to any infinite series expansions. Further, an explicit formula is given for the velocity distribution on the surface of an elliptic cylinder, in the case of absence of circulation. Finally, as an addendum, the critical Mach numbers for the flow past elliptic cylinders with their major axes perpendicular to the undisturbed flow are calculated for a series of values of their fineness ratios.

Pressure Distribution Investigation of an N.A.C.A. 0009 Aerofoil with a 30 per cent. Chord Plain Flap and Three Tabs. (M. B. Ames and R. I. Sears, N.A.C.A. Tech. Note No. 759, May, 1940.) (86/2 U.S.A.)

Pressure distribution tests of an N.A.C.A. 0009 aerofoil with a 30 per cent. chord plain flap and three plain tabs, having chords 10, 20, and 30 per cent. of the flap chord, were made in the N.A.C.A. 4- by 6-foot vertical tunnel. The purpose of these tests was to continue an investigation to supply structural and aerodynamic section data that may be applied to the design of horizontal and vertical tail surfaces.

The results are presented as diagrams of resultant pressures and of resultant pressure increments for the aerofoil with the flap and the 20 per cent. chord tab. Increments of normal force and hinge moment coefficients for the aerofoil, the flap, and the three tabs are also given.

At all unstalled flap and tab deflections, the experimental distributions agree well with those calculated by an analytical method. The agreement is poor, however, when the stalled or the unstalled condition of the flap or the tab deflected alone was changed to an unstalled or stalled condition by the simultaneous deflection of both the flap and the tab. This poor agreement between

the experimental and the calculated results is attributed to the fact that the coefficient increments for these critical conditions are not additive, as they must be to obtain good agreement.

In the application of these data for design purposes, it should be remembered that, for all cases, gaps were completely sealed, resulting in higher peak pressures at the hinge axes and in higher hinge moment and normal force coefficients than would have been obtained with unsealed gaps. It should also be noted that only the values of the normal force coefficients were corrected for tunnel effects.

Pressure Distribution Investigation of an N.A.C.A. 0009 Aerofoil with an 80 per cent. Chord Plain Flap and Three Tabs. (M. B. Ames and R. I. Sears, N.A.C.A. Tech. Note No. 761, May, 1940.) (86/3 U.S.A.)

Pressure distribution tests of an N.A.C.A. 0009 aerofoil with an 80 per cent. chord plain flap and three plain tabs, having chords of 10, 20, and 30 per cent. of the flap chord, were made in the N.A.C.A. 4- by 6-foot vertical tunnel. Section data suitable for application to the design of horizontal and vertical tail surfaces were obtained.

Resultant pressure diagrams for the aerofoil with the flap and the 20 per cent. chord tab are presented. Plots are also given of increments of normal force and hinge moment coefficients for the aerofoil, the flap, and the three tabs. A comparison of some characteristic slopes for the 30, the 50, and the 80 per cent. chord flaps, tested in the general investigation of plain flaps for control surfaces, is included. The data now presented complete the investigation of an N.A.C.A. 0009 aerofoil with a wide range of flaps and tabs. The results should be applicable to the design of any plain flap and tab combination likely to be used for horizontal or vertical tail surfaces. The incremental data are believed to be applicable to other conventional aerofoils of approximately the same shape and thickness. In applying the data it has to be remembered that they were obtained with hinged surfaces having completely sealed gaps and that only the values of the aerofoil normal force coefficient have been corrected for tunnel effects. Although the other coefficients are uncorrected they are believed to be conservative for application in stress analysis.

The Flow of a Compressible Fluid Past a Sphere. (C. Kaplan, N.A.C.A. Tech. Note No. 762, May, 1940.) (86/4 U.S.A.)

The flow of a compressible fluid past a sphere fixed in a uniform stream is calculated to the third order of approximation by means of the Janzen-Rayleigh method. The velocity and the pressure distributions over the surface of the sphere are computed and the terms involving the fourth power of the Mach number, neglected in Rayleigh's calculation, are shown to be of considerable importance as the local velocity of sound is approached on the sphere. The critical Mach number, that is, the value of the Mach number at which the maximum velocity of the fluid past the sphere is just equal to the local velocity of sound, is calculated for both the second and the third approximations and is found to be respectively, $M_{cr}=0.587$ and $M_{cr}=0.573$.

Wind Tunnel Investigation of Two Aerofoils with 25 per cent. Chord Gwinn and Plain Flaps. (M. B. Ames, N.A.C.A. Tech. Note No. 763, May, 1940.) 86/5 U.S.A.)

Aerodynamic force tests of an N.A.C.A. 23018 aerofoil with a Gwinn flap having a chord 25 per cent. of the over-all chord and of an N.A.C.A. 23015 aerofoil

with a plain flap having a 25 per cent. chord were conducted in the N.A.C.A. 7- by 10-foot wind tunnel to determine the relative merits of the Gwinn and the plain flaps.

The tests indicated that, based on speed range ratios, the plain flap was more effective than the Gwinn flap. At small flap deflections, the plain flap had the lower drag coefficients at lift coefficient values less than 0.70. For lift coefficients greater than 0.70, however, the Gwinn flap at all downward flap deflections had the lower drag coefficients.

Experimental Results with Aerofoils Tested in the High Speed Tunnel at Guidonia. (A. Ferri, Atti di Guidonia, No. 17, Sept., 1939. Translation available as N.A.C.A. Tech. Memo., No. 946.) (86/6 Italy.)

The seven sections tested were made up of circular arcs or straight lines with sharp leading and trailing edges, the thickness ratio being of the order of 5 per cent. whilst the chord varied between 48 and 60 mm. Lift, drag and moment curves were determined in the Guidonia supersonic tunnel at Mach numbers 1.85 and 2.13 for four of the sections (span 60 cm.), pressure distribution being also measured for two of them. Optical flow investigations were carried out on the three remaining sections (span 40 cm.). The aerodynamic characteristics of all the seven aerofoils were also calculated theoretically. The following are some of the main conclusions drawn by the author:—

(1) The lift coefficient is practically a straight line function of the angle of attack up to very high values of the incidence ($\alpha \sim 28°$). The slope of this line is however very low and the maximum value of C_L at these angles is of the order of 0.8.

(2) For values of α in excess of $\pm 5°$, the resistance coefficient increases rapidly. Maximum C_L/C_R is obtained in the neighbourhood of 6°, the value being of the order of 5.

(3) The calculated lift coefficients are appreciably above the experimental values and the slope of the lift coefficient line is also greater.

(4) The calculated drag coefficients, although no allowance for friction is made, are in many cases above the experimental values.

(5) The integration of the experimental pressure distribution curves is in fair agreement with the measured lift.

(6) The deflection of the shock wave at the leading edge as measured from flow photographs is in satisfactory agreement with theory.

(7) Both the pressure distribution measurements and flow photographs show distinct evidence of flow separation brought about by friction in the boundary layer. In the present state of our knowledge of gas dynamics, no aerofoil theory exists that takes viscous forces into account. Further researches on these lines are urgently needed.

A Simple Approximate Method for Obtaining the Spanwise Lift Distribution. (O. Schrenk, Luftwissen, Vol. 7, No. 4, April, 1940, pp. 118-120. Translation available as N.A.C.A. Tech. Memo., No. 948.) (86/7 Germany.)

The plausible assumption is made that the real lift distribution lies between an ideal distribution independent of wing shape and a distribution determined in a simple manner by the wing shape.

The ideal distribution is that of minimum induced drag and constant induced downwash velocity (*i.e.*, elliptic distribution for the monoplane) whilst the distribution dependent on shape is proportional to αt at each point of the wing.

In the case of an untwisted monoplane wing, the semi-ellipse of equal area with the chord distribution curve is drawn and the required lift distribution is obtained

by forming the arithmetical mean between the two curves. In the case of a twisted wing (including wings with aileron or flap deflection) the zero lift direction of the whole wing is first determined and for all further computations, both the angle of attack and the twist are measured from this direction, use being made of the formula

$$\frac{dA}{dx}=\tfrac{1}{2}\,q\,\frac{dc_a}{d\alpha}\,\alpha\,\left\{\,t\,(x)+\frac{4}{\pi}\bar{t}\,\sqrt{1-\left(\frac{x}{b/2}\right)^2}\,\right\}+\tfrac{1}{2}\,q\,\frac{dc_a}{d\alpha_\infty}\,\delta\,(x)\,t\,(x)$$

In the above $\delta\,(x)$ = angle between reference line of wing and local zero lift direction. $dc_a/d\alpha$ and $dc_a/d\alpha_\infty$ can generally be taken as constant along the span. The author gives a number of comparisons of lift distribution as calculated by the above approximate method with those obtained by the more accurate but much more laborious method of Multhopp, showing very good agreement. By the decomposition into an ideal, plan form and twist distribution, simple and time-saving relations may be set up for frequently repeated computations of bending moments, transverse forces and torsional moments along the span. The method can also be applied to certain cases when the usual method fails completely (monoplane with end plates).

On the Theory of Unsteady Planing and the Motion of a Wing with Vortex Separation. (L. Sedov, C.A.H.I. Report No. 252. Translation available as N.A.C.A. Tech Memo., No. 942.) (86/8 U.S.S.R.)

In a fundamental paper on the theory of planing (R.T.P. Translation No. 331) Wagner has shown that for small angles of attack, the lift force on a planing surface is equal to half the lift on a wing of the same profile (steady motion in both cases). The author shows that the more general planing problems, including unsteady motion, can also be most easily attacked by making use of the theory of thin wings together with that of waves of small amplitudes. In the study of unsteady motion, it is usually assumed that the forces at each instant coincide with those of a corresponding steady motion defined by the same geometric parameters (position and velocity of body). The errors involved in this assumption (hypothesis of stationary forces) are investigated by the author. In the particular case of unsteady planing of a flat plate, the resultant lift $\gamma=\gamma_1+\gamma_2+\gamma_3$ of which only γ_2 is given by the " stationary " hypothesis. The γ_1 term corresponds to the so-called " added mass " whilst γ_3 takes into account the effect of the horizontal velocity of the fluid on the free surface (absent in steady planing). All three forces act perpendicularly to the plate, γ_1 and γ_2 at the centre, and γ_3 at a distance from the leading edge equal to γ_4 of the wetted length. In the case of accelerated motion, the water may break away and γ_3 become negative. Adding the inertia effect to the lift force as calculated from the stationary hypothesis thus gives too great a value for the total lift, the reverse holding true for retarded motion.

The author concludes his paper by considering the case of the steady harmonic oscillations of a plate, the lift forces obtained by the general formula being compared with those obtained by the stationary hypothesis and those given by Perring and Glauert in R. and M. 1,493. These authors assume that the ratio n of the actual wetted length to the length under the surface level is equal to unity. Under these conditions the lift values given by Perring and Glauert agree with those given by the author using the " stationary " hypothesis. The values obtained by the more general formula differ however appreciably, depending on the type of oscillation considered.

Windshield Wipers. (Inter. Avia., No. 733, 28/10/40, p. 8.) (86/9 U.S.A.)

Rotating windshield wipers for aircraft have been in use with considerable success in the United States for some time. A device of this type, manufactured

by the Air Associates Inc., has been described in Inter. Avia. No. 638. Meanwhile, the N.A.C.A. has carried out extensive tests with windshield wipers operating with de-icer fluids and heating installations as part of its programme to eliminate the icing hazard on aeroplanes (Technical Note, No. 754). It is now reported that the aircraft of American Airlines Inc. are being fitted with return stroke type wipers which for a maximum of 480 return strokes a minute require one-half of a horse-power. The spray of de-icer fluid as well as the wiper's speed can be regulated by the pilot; the functioning of the device is unaffected by high winds created by the aircraft at speeds of up to 250 m.p.h.

Diving Brakes on Ju 87. (Inter. Avia., No. 731, 12/10/40, p. 9.) (86/10 Germany.)

Unlike the arrangements known in the Italian and American dive bomber types which aim at a limitation of the diving speed by the use of normal, downward deflection split-type flaps mounted at a point of the chord which corresponds to the rear spar, or by split-type flaps deflecting symmetrically upwards and downwards, the air brakes of the Ju 87 are mounted on the underside of the wing just ahead of the front spar. A small portion of the elevator unit still lies in the turbulent zone of the brake; in order to reduce such disturbances, the flap does not continue right to the wing cover and its surface is interrupted by means of a slot. The inter-connection between the air brake and the landing flap is described in the Swedish patent No. 99,515 which has been taken out by the Junkers Aircraft and Engine Company. A patent protects:—" An aircraft with dive brakes arranged on the wings, characterised by the fact that in the operating mechanism of the landing flaps inter-connecting members are incorporated in a way that the angular motion of the landing flaps located in the flight direction at the rear of the diving brakes is diminished or made entirely impossible when the diving brakes are deflected." A development of the arrangement described is formed by the air brakes mounted on the Ju 88 twin-engined bomber. The " venetian blind " type of brake is several times larger than the brakes of the Ju 87; the positive mechanical connection with the landing flaps is retained; the axis of rotation, on the other hand, is located on the front spar, so that in normal flight the brake surface lies flush with the underside of the wing.

Spin Tests of a Low Wing Monoplane in Flight and in the Free Spinning Wind Tunnel. (O. Seidman and W. H. McAvoy, N.A.C.A. Tech. Note No. 769, July, 1940.) (86/14 U.S.A.)

Comparative full-scale and model spin tests were made with a low wing monoplane in order to extend the available information as to the utility of the free spinning wind tunnel as an aid in predicting full-scale spin characteristics.

For a given control disposition the model indicated steeper spins than were actually obtained with the aeroplane, the difference being most pronounced for spins with elevators up. Recovery characteristics for the model, on the whole, agreed with those for the aeroplane, but a disagreement was noted for the case of recovery with elevators held full up. Free spinning wind tunnel tests are a useful aid in estimating spin characteristics of aeroplanes, but it must be appreciated that model results can give only general indications of full-scale behaviour.

Tyre Wear on Runways (*B. Pt. No.* 516,738). (Inter. Avia., No. 731, 12/10/40, p. 11.) (86/11 Great Britain.)

The use of artificial landing runways of concrete or with surface aggregates of asphaltic concrete, macadam, and so on, has resulted in a considerable reduction in the life of aircraft wheel tyres. Higher landing speeds, heavy tyre loads

and lower tyre pressure further contribute to the decrease in tyre life. The additional tyre wear on hard, abrasive surfaces results mainly from the following factors:—Acceleration upon landing, deformation of the tyres in close taxying turns, slip due to the use of brakes, lateral tread scrubbing due to misalignment and lateral motion. The surmounting of the inertia of the wheels which at the moment of ground contact are stationary and which are brought up to the rotating speed corresponding to the taxying speed solely by ground friction, can add greatly to tyre wear in large aeroplanes. This type of wear is claimed to have been eliminated by a device for which Vickers-Armstrongs, Ltd., have been granted British Patent No. 516,738. The plan is to spin the wheels by means of wind cups on the wheels themselves or on the tyres.

Measurement of the Period of Natural Vibration of an Airscrew Blade. (J Obata and Y. Yosida, Aer. Res. Inst., Tokyo, Vol. 15, No. 191, July, 1940.) (86/12 Japan.)

The results of previous studies by the authors in the electrical method of measuring small vibrations with the aid of a triode valve, together with its applications to the measurement of vibrations of airscrew blades, has been given in a previous report (No. 103).

Recently, in connection with the study of airscrew flutter, the need of accurate measurements of bending as well as of torsional vibrations of an airscrew blade arose, resulting in the application of the electrical method with very satisfactory results. At that time, certain improvements and developments were made on our former method, and are described in the present paper. These consisted chiefly in the provision of a set of suitable electric filters for sorting out different types of vibrations existing simultaneously and improvements in the design of the electrode.

Flight Investigation of Control Stick Vibration of the YG-1B Autogiro. (F. J. Bailey, N.A.C.A. Tech. Note No. 764, June, 1940.) (86/13 U.S.A.)

As a preliminary step in an investigation of control stick vibration in direct control autogiros, the periodic variations in the moments transmitted through the control system of a YG-1B autogiro were recorded in flight. The results of the measurements are presented in the form of coefficients of Fourier series expressing the varying part of the lateral and the longitudinal moments acting between rotor and fuselage at the control trunnions.

The most important component of the variation in stick force was found to have a frequency of three times the rotor speed and an amplitude that rose from negligible values at tip speed ratios below 0.20 to ± 5.2 pounds longitudinally and ± 3.2 pounds laterally at tip speed ratios of 0.35. Variations in stick force at all other frequencies were small in comparison with those at three times the rotor speed.

Transient Effects of the Wing Wake on the Horizontal Tail. (R. T. Jones and L. F. Fehlner, N.A.C.A. Tech. Note No. 771, August, 1940.) (86/15 U.S.A.)

A theoretical investigation is made of the effect of the wing wake on the lift of the horizontal tail surfaces. Expressions have been developed for this effect by taking into account the growth of wing circulation and wing wake, the time interval represented by the tail length and the development of lift by the tail. The tail surface was considered to be located directly in the wake where the effect is a maximum. The effect of tail length was investigated and it was found that the results obtained from computations covering a typical case could be

extrapolated to take account of this factor in a satisfactory manner. The theory has been applied to a specific case to show the magnitude of the effect to be expected. It may also be extended to show the effects of vertical gusts. The lift of the tail surface due to interference from the wing during penetration of the gust may be calculated with the aid of curves given, provided that the variation in angle of attack of the wing is known. The lift independently developed by the action of the gust on the tail surface may be determined by the method described in N.A.C.A. Tech. Rept., No. 681. The two effects are additive.

Analysis of Wind Tunnel Data on Directional Stability and Control. (H. R. Pass, N.A.C.A. Tech. Note No. 775, Sept., 1940.) (86/16 U.S.A.)

Available wind tunnel data on static directional stability and control have been collected and studied. Methods based on these studies are given for evaluating the aerodynamic characteristics of vertical tail surfaces and their contribution to static directional stability and control. Special attention has been paid to the end-plate effect of the horizontal tail on the vertical tail and to the sidewash induced by the fuselage and the trailing vortex system from the wing. Methods based on limited data for fuselages and hulls, wings, and fuselage wing combinations are also given for estimating the contribution of the wing and the fuselage to directional stability.

This paper does not attempt to establish criteria for directional stability and control; rather, the emphasis is placed on providing some basis for design to specified criteria. An example applying the design methods has been included.

The Aileron as an Aid to Recovery from the Spin. (A. I. Neihouse, N.A.C.A. Tech. Note No. 776, Sept., 1940.) (86/17 U.S.A.)

As part of a general investigation by the N.A.C.A. of factors that affect the spin, the use of the aileron as an aid to recovery from the spin was studied. Tests of ten different models, covering a wide range of mass distribution, were made in the N.A.C.A. free-spinning tunnel to determine the effects of a large downward deflection of the outboard aileron and of normal angular deflections of the ailerons upon recovery characteristics.

The results indicate that the direction of aileron setting, with or against the spin, which will aid recovery from the spin depends upon the aeroplane weight distribution. For monoplanes and for biplanes with lower wing ailerons, ailerons with the spin will be favourable w en the weight is distributed chiefly along the fuselage (single-engine aeroplanes) and ailerons against the spin will be favourable when the weight is distributed chiefly along the wings (multi-engine aeroplanes). Downward movement of the outboard aileron through a large angle will not always be effective in aiding recovery, the effectiveness of such a movement also being dependent upon the weight distribution of the aeroplane.

Notes on the Stalling of Vertical Tail Surfaces and on Fin Design. (F. L. Thompson and R. R. Gilruth, N.A.C.A. Tech. Note No. 778, October, 1940.) (86/18 U.S.A.)

The important aspects of the stalling of vertical tail surfaces, the type of instability encountered and the possibilities of its inadvertent occurrence are discussed on the basis of data accumulated in the N.A.C.A. flight research laboratory for the flying qualities of various aeroplanes. Flight tests of a twin-engine aeroplane in which the vertical fin area was increased are quoted to illustrate the influence of directional stability on the behaviour of an aeroplane when the tail stall takes place. Inadequate directional stability in certain modern designs appears to be due to the effect of refinement in fuselage shape and a general

increase in wing loading. The properties and application of dorsal fins are discussed. In addition the chief factors regulating the requirements for conventional fin area are given, in which connection a simplified criterion for directional stability is presented. It is concluded that the directional instability at large angles of sideslip is associated with fin stalling, but that fin stalling does not necessarily produce instability. It is when the stalling condition can be produced by a smaller rudder angle than that at which the rudder tends to float with the fin stalled, that trouble occurs. It follows that a reduction in the rudder floating angle for the stalled condition, as well as an increase in the rudder angle required to produce the stalled condition, would be beneficial. In order further to clarify the problem and provide the proper quantitative basis for design, considerable research on the characteristics of various tail forms and on the flow conditions at the tail are needed.

Aerodynamic Heating and the Deflection of Drops by an Obstacle in an Air Stream in Relation to Aircraft Icing. (A. Kantrowitz, N.A.C.A. Tech. Note No. 779, Oct., 1940.) (86/19 U.S.A.)

The N.A.C.A. has been conducting a programme to develop a method of using engine exhaust heat to prevent or to remove ice formations on aircraft. The chief object of this paper is to provide information that will be useful to persons attempting to apply this method.

Two subjects are included in the present investigation:—

1. The temperature rise of surfaces exposed to boundary layer friction has been studied. This natural temperature rise is expected materially to reduce the amount of heat required to keep a surface in high speed flight above the freezing temperature.
2. The paths of water drops in an air stream disturbed by the presence of a circular cylinder have been numerically calculated. The calculation of these paths leads to information on the percentage of the swept area cleared of drops by the circular cylinder. This information should be of assistance in estimating the heat required to overcome the supercooling of drops that strike the wing.

Measured Moments of Inertia of 32 Aeroplanes. (W. Gracey, N.A.C.A. Tech. Note No. 780, Oct., 1940.) (86/20 U.S.A.)

A compilation of the experimentally determined moments of inertia of 32 aeroplanes is presented. The measurements were obtained at the laboratories of the N.A.C.A. by means of a pendulum method. The aeroplanes tested are representative of several types of aircraft of gross weight less than 10,000 pounds.

The results are presented in coefficient as well as in dimensional form. An elementary analysis of the data disclosed the possibility of grouping the results according to wing type of the aeroplane, as low wing monoplanes, parasol and high wing monoplanes, and biplanes. The data are shown to provide a convenient means of rapidly estimating the moments of inertia of other aeroplanes. A three-view drawing of each of the 32 aeroplanes is included.

This note supersedes N.A.C.A. Technical Note No. 375.

Mathematical Analysis of Aircraft Intercooler Design. (U. T. Joyner, N.A.C.A. Technical Note No. 781, Oct., 1940.) (86/21 U.S.A.)

The dimensions of an aircraft intercooler of the cross flow type fulfilling a given set of design conditions is investigated mathematically, making use of published data on heat transfer and pressure drop. These design conditions are:—

(1) Total mass flow of engine air.
(2) Inlet temperatures of engine and cooling air.
(3) Required engine air temperature at cooler outlet.
(4) Characteristics of aircraft carrying cooler.
(5) Physical characteristics of cooling air.

The total power consumed by the intercooler (sum of power used in forcing cooling and engine air through the cooler and the power required to transport the cooler) is used as a criterion of merit.

The analysis is applied to the case of a 1,000 h.p. engine operating at 25,000 feet, flying speed 300 m.p.h. The engine air enters at 280°F. and leaves at 80°F., whilst the cooling air enters at −80°F.

The following table is for a series of mass flows of the cooling air, the dimensions of the cooler being adjusted in each case to produce the necessary heat flow.

M_c	H ft.	L_c ft.	L_e ft.	Intercooler volume cu. ft.	P_t lb./sq. ft.	Δp_c lb./sq. ft.	Δp_e h.p.
1.00	69.91	0.018	0.470	0.583	0.208	5.57	2.50
0.30	19.72	0.063	0.497	0.617	0.745	5.89	2.66
0.15	8.64	0.144	0.568	0.704	1.700	6.72	3.03
0.05	1.29	0.964	1.270	1.576	11.41	15.04	6.78
0.04	0.42	2.974	3.136	3.890	35.24	37.14	16.75

In the above table,

M_c = mass flow of cooling air in slugs per second (1 slug/sec. = 32 lb./sec.).
H = height of intercooler (ft.).
L_c = length of cooling air passage (ft.).
L_e = length of engine air passage (ft.).
Δp_c = pressure drop of cooling air (lb./sq. ft.).
Δp_e = pressure drop of engine air (lb./sq. ft.).
P_t = total power consumed (h.p.).

The design with $M_c = 0.15$ slugs/sec. ($\sim$ 2 lb./sec.) is suggested as forming the best compromise, the h.p. absorbed being of the order of 3.

Vibration Patterns of Propeller Blades. (G. S. Baker, Engineering, Vol. 150, No. 3,910, 20/12/40, pp. 484-486; No. 3,911, 27/12/40, pp. 518-9.) (86/22 Great Britain.)

The experiments were carried out on two-bladed model ship propellers, 1 foot in diameter, the relatively heavy boss being firmly secured to a massive iron plate. Seven models were tested, three being of symmetrical outline whilst the remaining four had skewed back blades. All the blades were made flat on the driving face which was in a horizontal plane when the model was secured to the base plate. Vibrations were excited by means of an electro magnet supplied with alternating current, the frequency of which could be varied over wide limits. Resonance was detected by the loudness of the note emitted and the vibration form determined by sand patterns. Two principal modes of vibration, *i.e.*, flexural and torsional were investigated. At very high frequencies a lateral vibration of the blade was also observed.

A large number of photographs showing these modes of vibration are given. For the particular models tested, the fundamental flexural vibration frequency (nodal line near hub) was of the order of 500/sec. whilst the fundamental torsional

vibration (nodal line radiating outwards from hub to tip) had a frequency of about 1,500 vibrations/sec.

The second, third and fourth order flexural vibrations have frequency ratios of about 3·5, 7 and 10 respectively with regard to the primary. The second order torsional vibration has a frequency ratio of only 1.6. Higher torsionals are generally combined with bending vibrations and the resultant pattern is very complicated.

For a particular blade of parabolic outline and a straight thickness line from root to tip, the fundamental frequency f can be calculated and is given by the equations :—

$$\left.\begin{aligned} f_f &= (0.3\, t/l^2)\, r\sqrt{(gE/\rho)} \quad \text{(flexural)} \\ \text{and } f_t &= (1.0/b_r l)\, t_r \sqrt{(gN/\rho)} \quad \text{(torsional)} \end{aligned}\right\} \text{cycles/sec.}$$

where b_r and t_r are chord and thickness at root in inches.

l = free length of blade from root to tip.
ρ = density of material in lb./cub. in.
$g = 32 \times 12$.

The experimental results can be represented by similar equations given below.

$$f_f = 0.305\, (t_r/l^2)\, \{ (b_r/b_m)\, (t_m/t_r) \}^{\frac{1}{2}} \sqrt{(gE/\rho)}$$
$$f_t = 0.92\, (t_h/b_h l)\, (b_r/b_m) \sqrt{(gN/\rho)}$$

where b_h and t_h = breadth and maximum thickness of blade at $l/2$.
b_m and t_m = mean breadth and mean maximum thickness.

These formulæ can only be regarded as useful for blades with thin edges and rounded backs. Moreover, an allowance will also have to be made for the fact that the experimental blades were not twisted, *i.e.*, their flat lower surface was parallel to the bed plate for the whole span.

The author's experiments form part of an investigation on the troublesome vibrations accompanied by a " singing " tone occasionally met with in ships' propellers. In a particular case, the fundamental of the note emitted was of the order 180-300 cycles/sec. for an 18-foot propeller. The above equations show that both flexural and torsional frequencies vary inversely as l for similar propellers.

The corresponding frequency of the 1-foot model is thus of the order 3,000-5,000 vibrations/sec., *i.e.*, third and fourth order flexural.

Italian Experiments on Jet Propulsion. (Inter. Avia., No. 733, 28/10/40, p. 6.) (86/23 Italy.)

Inter. Avia., No. 694-95, pointed to the plans of Engineer Campini, of the Caproni group, which aimed at the realisation of a high level high speed aircraft with jet propulsion. On August 27th the first flight of such a design was effected from the Milan aerodrome of Forlanini in the presence of Divisionnaire-General Alberto Briganti, the Commander of No. 1 Air Zone. According to the " Popolo d'Italia," the machine is built entirely of metal, has a gross weight of about 8,800 lb., retractable landing gear and a pressure cabin. Piloted by Colonel de Bernardi, of the Caproni works, the machine, driven solely by the reaction of ejected gases, accomplished a flight of ten minutes' duration. The Italian source claims the first flight of this " rocket-drive aircraft " to be the prelude to a revolution in the design of aircraft and power plant installations, without, however, dealing in any detail with the work that has been accomplished to overcome the difficulties hitherto encountered in the construction of jet-propulsion aircraft; it is merely stated that the research work of Engineer Campini, extending over decades, has finally led to the development of a power plant whose efficiency is not below that of the engine airscrew combination even at conventional speeds.

A Method of Measuring Piston Temperatures. (B. Pinkel and E. J. Manganiello, N.A.C.A. Tech. Note No. 765, June, 1940.) (86/24 U.S.A.)

A method employing thermocouples to measure the temperatures of engine pistons operating at high speeds has been developed. The thermocouples installed on the moving piston are connected to a potentiometer outside the engine by means of pneumatically operated plungers. These make contact with the piston thermocouples for about ten crankshaft degrees at the bottom of the piston stroke. The equipment operates satisfactorily at engine speeds of 2,400 r.p.m. and shows promise of successful operation at higher speeds. The accuracy of measurement is unaffected by speed within the range tested and its dependence on percentage duration of contact may be obviated by the use of a sufficiently sensitive galvanometer for a balance indicator. Piston temperatures were measured in a liquid-cooled compression ignition engine and in an air-cooled spark ignition engine with fuel injection. In the latter case the increase in piston temperature with increased load and increase in head and barrel temperature indicates the pressing need for an investigation of possible means for reducing the operating temperatures of pistons.

A Study of the Air Movement in Two Aircraft Engine Cylinders. (D. W. Lee, N.A.C.A. Tech. Note No. 766, July, 1940.) (86/25 U.S.A.)

Studies were made of the air movements in the N.A.C.A. glass cylinder apparatus using cylinder heads similar to those on the Wright R-1820-G engine (I) and the Pratt and Whitney "Wasp" engine, as modified by the Eclipse Aviation Corporation to use fuel injection equipment (II). The air movements were made visible by mixing small feathers with the air; high speed motion pictures were taken of the feathers as they swirled about inside the glass cylinder. The test engine speeds were 350, 500 and 1,000 r.p.m. Motion pictures were also taken of gasoline sprays injected into the cylinder during the intake stroke. The air movement in the cylinder using cylinder head (I) was very turbulent during the intake stroke. During the second half of the intake stroke, a very slow rotation of the air about the cylinder axis began. The turbulence died out during the compression stroke, but the rotation continued at a reduced rate until the end of the cycle. The air movement in the cylinder when using head (II) took the form of a vertical loop during the intake and compression strokes; some turbulence was also present. The loop movement died out before the beginning of the expansion stroke, leaving only a slight turbulence. There appeared to be no difference in the time required for vapourisation of gasoline sprays injected into the cylinder when using the two types of head.

The Development of the Brown Boveri Axial Compressor. (Seippet, Brown Boveri Review, May, 1940, pp. 108-113.) (86-27 Great Britain.)

Some of the aerodynamic principles involved in the design of axial compressors are dealt with, and their influence upon blade shape discussed. Notes are added on the experimental development of the axial blower, and a review is made of the field of its application.

(Abstract supplied by Research Dept., Metropolitan-Vickers.)

Analysis of Cylinder Pressure Indicator Diagrams showing Effects of Mixture Strength and Spark Timing. (H. C. Gerrish and F. Voss, N.A.C.A. Tech. Note No. 772, Aug., 1940.) (86/26 U.S.A.)

An investigation was made to determine the effect of mixture strength and of normal as well as optimum spark timing on the combustion, on the cylinder temperature, and on the performance characteristics of an engine. A single

cylinder test unit utilising an air-cooled cylinder and a carburettor and operating with gasoline having an octane rating of 92 was used. The investigation covered a range of fuel-air ratios from 0.053 to 0.118. Indicator diagrams and engine performance data were taken for each change in engine conditions.

Examination of the indicator diagrams shows that for fuel-air ratios less than and greater than 0.082 the rate and the amount of effective fuel burned decreased. For a fuel-air ratio of 0.118 the combustion efficiency was only 58 per cent. Advancing the spark timing increased the rate of pressure rise. This effect was more pronounced with leaner mixtures.

Italian High Speed Aeroplane Engines. (C. F. Bona, Paper presented to the Volta Conference, Oct., 1935. Translation available as N.A.C.A. Tech. Memo., No. 944.) (86/28 Italy.)

Some design particulars of the Fiat A.S.6 engine which gained the speed record over 3 km. for Italy in 1934 are given. This engine consists of two separate A.S.5 V engines placed in tandem, each driving its own propeller. The propellers are arranged concentrically in the nose of the front engine, the driving shafts (two tubes one inside the other) being located inside the V. One of these shafts is driven from the rear end of the front engine whilst the inside shaft is driven from the front of the rear engine. The two reduction gears are similar, but the crankshafts and therefore the propellers rotate in opposite directions. The lengths of the two shafts is thus practically the same (length of one engine) and no torsional difficulties were experienced. Since only one supercharger is fitted, which is driven by the rear engine whilst supplying compressed charge to both, the net h.p. transmitted by the rear engine differs by the negative work (200 h.p.) from that available at the propeller driven from the front engine. In order to ensure the same rotational speed the pitches of the two propellers are made slightly different. The original A.S.5 engines (12-cylinder V, 138 × 140 mm.; separate cylinders, welded steel jackets) developed about 1,000 h.p. at 3,200 r.p.m. and were not fitted with a supercharger. The two A.S.5 engines forming the new unit had certain parts stiffened and were boosted to intake pressure varying between 7 and 12 lb. per sq. in. Under these conditions the combined unit developed up to 3,000 h.p. at 3,300 r.p.m. The article deals mainly with various difficulties encountered whilst developing and testing, damage due to backfires being the principal source of trouble. This was partly due to faulty mixture distribution and partly to changes in ignition timing due to torsional oscillations of the drive. The fuel used had the following composition:—

Petrol	55%	}
Ethyl alcohol ...	23%	} + 1.5 per cent. Tet. Ethyl Lead.
Benzol	22%	}

The mixture was supplied by four down draught carburettors placed at the blower intake and distributed to the cylinders by a central pipe of relatively large capacity placed inside the V and provided with branches for every two cylinders.

Viscosity Characteristics of Lubricating Oils as Related to their Chemical Structure. (B. Yamaguchi, Aer. Res. Inst., Tokyo, Rept. No. 192, Aug., 1940. In Japanese.) (86/29 Japan.)

It is shown that no clear relationship exists between chemical structure and viscosity index (Viscositatspolhöhe) of high molecular weight hydrocarbons, but that the viscosity temperature coefficient for liquids of equal viscosity is a function only of chemical structure. For a number of synthetic high molecular weight hydrocarbons the viscosity temperature coefficients, at the respective temperatures at which all the liquids have a viscosity of 100 centistokes, have been calculated by means of Walther's viscosity temperature equation. It was found that the

calculated coefficients are always definitely related to chemical structure. It is concluded that the greater the "degree of entanglement" of a hydrocarbon molecule, defined by the size of cyclic nuclei or the length of paraffinic side chains in conjunction with the size and allocation of branched chains in the molecule, the smaller is the value of the viscosity temperature coefficient (or "structure viscosity index," $-[(dv/dt)\,v=100 \text{ c.s.} + 5] \times 100$). A criterion for grading the viscosity characteristics of hydrocarbons is provided both by the values of viscosity and "structure viscosity index." For compounds of comparable viscosities, the viscosity characteristics are better the smaller the structure viscosity index. The molecular structure necessary to give optimum viscosity characteristics is discussed and it is shown that the beneficial effect of addition of agents such as paratone to commercial lubricants can be reasonably explained by the idea of "structure viscosity index."

The Effects of Engine Speed and Mixture Temperature on the Knocking Characteristics of Several Fuels. (D. W. Lee, N.A.C.A. Tech. Note No. 767, July, 1940.) (86/30 U.S.A.)

Six 100 octane and two 87 octane aviation engine fuels were tested in a modified C.F.R. variable compression engine at 1,500, 2,000, and 2,500 r.p.m. The mixture temperature was raised from 50° to 300°F. in approximately 50° steps and, at each temperature, the compression ratio was adjusted to give incipient knock as shown by a cathode ray indicator. The results are presented in tabular form.

The results are analysed on the assumption that the conditions which determine whether a given fuel will knock are the maximum values of density and temperature reached by the burning gases. A maximum permissible density factor, proportional to the maximum density of the burning gases just prior to incipient knock, and the temperature of the gases at that time were computed for each of the test conditions. Values of the density factor were plotted against the corresponding end gas temperatures for the three engine speeds and also against engine speed for several end gas temperatures.

The maximum permissible density factor varied only slightly with engine speed, but decreased rapidly with an increase in the end gas temperature. The effect of changing the mixture temperature was different for fuels of different types. The results emphasise the desirability of determining the anti-knock values of fuels over a wide range of engine and intake air conditions rather than at a single set of conditions.

Correlation of Knocking Characteristics of Fuels in an Engine having a Hemispherical Combustion Chamber. (A. M. Rothrock and A. E. Biermann, N.A.C.A. Tech. Note No. 768, July, 1940.) (86/31 U.S.A.)

Data are presented to show the effects of inlet air pressure, inlet air temperature, and compression ratio on the maximum permissible performance obtained with a cylinder having a hemispherical dome combustion chamber. The five aircraft engine fuels used have octane numbers varying from 90 to 100 plus 2 *ml* of tetraethyl lead per gallon. The data were obtained on a $5\frac{1}{4}$-inch by $4\frac{3}{4}$-inch liquid-cooled engine operating at 2,500 r.p.m. The compression ratio was varied from 6.0 to 8.9. The inlet air temperature was varied from 110° to 310°F. For each set of conditions, the inlet air pressure was increased until audible knock occurred and then reduced two inches of mercury before data were recorded. The results for each fuel can be correlated by plotting the calculated end gas density factor against the calculated end gas temperature. Measurements of spark plug electrode temperatures showed that, with two spark plugs, cutting off the switch to one spark plug lowered the electrode temperature of that plug from

a value of 1,365°F. to a value of 957°F. The results indicate that the surface temperatures of combustion chamber areas which become new sources of ignition markedly increase after ignition commences.

Ionisation in the Knock Zone of an Internal Combustion Engine. (C. E. Hastings, N.A.C.A. Tech. Note No. 774, Sept., 1940.) (86/32 U.S.A.)

The ionisation in the knock zone of an internal combustion engine was investigated. A suspected correlation between the intensity of knock and the degree of ionisation was verified and an oscillation in the degree of ionisation corresponding in frequency to the knock vibrations in the cylinder pressure was observed. Under suitable conditions the ionisation gap may be used to indicate knock.

Universal Compass Checking Bench. (Inter. Avia., No. 728, 19/9/40, pp. 3-4.) (86/33 Germany.)

For the periodical checking of direct reading and tele-compasses the Askania Werke A.G., Berlin-Friedenau, has developed a universal checking bench which permits the control of all compass models of up to 6.23 in. (160 mm.) diameter. During the checking process the surrounding magnetic fields and the position of the compasses are altered and the following properties tested:—Time required for re-setting after a 90 deg. deviation, angle of inversion and period of semi-oscillations, hunting, pivot friction and maximum permissible compass-rose inclination. In tele-compasses the setting precision at full directing force is also checked. The design of the checking bench is as follows:—

A rotatable axle carries a gear ring; three pedestals on the ring take the compass to be checked. The gear ring is rotated either by a hand crank or a synchronous motor. Three magnet coils connected to a 12-volt D.C. circuit serve to modify the magnetic fields. The synchronous motor driving the gear ring is provided with a gear box selected in such a way that the ring rotates through 360 degrees in one, two or three minutes, respectively. The spacing of the motor from the compass is large enough to eliminate all magnetic influence. A photo shows the mounting of a conventional direct-reading compass on the bench. The accessories such as the course element, vacuum pump, suction meter, and differential manometer are needed for the checking of tele-compasses.

Tensor Gauge. (Inter. Avia., No. 731, 12/10/40, p. 12.) (86/34 U.S.A.)

With the introduction of the all-metal monocoque type of construction in the aircraft industry, it was found necessary to develop a method of determining in a simple way the complete state of strain and stress in continuous sheets or thin plates under the influence of loads in the aeroplanes. The conventional experimental procedure consists of applying linear strain gauges in different directions during three successively repeated load cycles. The technical difficulties of repeating the test load cycle with exactly the same load distribution are well known. The efforts to develop a handy instrument which permits simultaneous measurement of stresses in three directions on certain points of the fuselage monocoque, at inaccessible junctions, etc., have led to the design of the Tensor gauge. The instrument is fastened to the specimen surface by a single central suction cup; three measuring cones, entirely independent of each other and forming the corners of an equilateral triangle, engage the specimen in a circular diameter of 30 mm. Each of the three movable legs is guided precisely radially; their movements are translated with imperceptible friction to a microscopic index reticule, the position of which is made readable by means of magnifying lenses. A strain of 1/10,000, which in aluminium corresponds to a

linear stress of approximately 1,000 lb. per sq. in., appears as one scale division; the total range amply covers any test requirements within the yield limits of the structural material.

Dynamical Stability of a Column Under Periodic Longitudinal Forces. (I. Utida and K. Sezawa, Aer. Res. Inst., Tokyo, Vol. 15, No. 193, Aug., 1940.) (86/35 Japan.)

Although there is a number of frequencies at which the vibration becomes unstable (resonance), the mode of vibration of the column is generally of the fundamental mode, *i.e.*, the ratio of the natural to the exciting frequency is of the order $\frac{1}{2}$, 2/2, 3/2, etc.

Although the periodic vibration of the column in the unstable or resonance condition is almost of sine form, the same form tends to change increasingly with increase in the order of resonances. It is likely that the wave form of the vibration of the column in the frequency intermediate between two neighbouring unstable conditions, contains both types of waves in these unstable conditions.

Experimental as well as mathematical result show that the resonance or instability condition depends on the magnitude of the vibrating forces applied. If the forces were not great, it would be impossible for the resonance or unstable condition to occur, from which it follows that the phenomena resemble those of resonance vibration with respect to the vibrational frequency and those of buckling with respect to the magnitude of the applied forces.

Some Experiments on the Forced Vibration of Varying Period. (K. Sezawa and W. Watanabe, Aer. Res. Inst., Tokyo, Vol. 15, No. 195, Aug., 1940.) (86/36 Japan.)

The resonance condition of an elastic bar under forces with frequency increasing or decreasing linearly with time, was investigated experimentally. The vibration of the same bar was excited electro-magnetically, the intensity of the force being constant for every vibration through the whole range of the varying frequency. A magnetic damper was added to the bar for ascertaining the effect of viscous damping on the resonance amplitude in the case of varying frequency.

Let dN/dt be the absolute speed of change of frequency and k the logarithmic decrement of free vibration in the case of dN/dt being zero. When k was not very large, the resonance amplitude diminished enormously with increase in dN/dt. On the other hand, when k was fairly large, no appreciable change in resonance amplitude occurred for different dN/dt. Although the resistance arising from viscous damping was operative in forced vibration as well as in free vibration, that due to change of cycle manifested itself only in the case of forced vibration. Furthermore, although the resonance amplitude was nearly the same provided the absolute values of dN/dt were given, there was some time lag in reaching the maximum amplitude. This feature was pronounced particularly in the case of large k. It was possible to construct empirical formulæ indicating the resonance amplitudes for any case of dN/dt.

The Lateral Stability of Equal Flanged Aluminium Alloy I Beams Subjected to Pure Bending. (C. Dumont and H. N. Hill, N.A.C.A. Tech. Note No. 770, Aug., 1940.) (86/37 U.S.A.)

Equal flanged beams of a special extruded I section of 27 ST aluminium alloy were tested in pure bending. Complete end fixity was not attained. Loading was continued until a definite maximum value had been reached. Tensile tests

were made on specimens cut from the flanges and the web of each beam. Compressive stress-strain characteristics were determined by pack compression tests on specimens cut from the flanges.

The critical stress at which equal flanged aluminium I beams subjected to pure bending become unstable may be determined from the equation

$$S_{cr}=(E_R/E)\{19{,}800{,}000/(KL)^2 Z\}\sqrt{\{I_1[J(KL)^2+6.58 I_1 h^2]\}}.$$

In both the elastic and the plastic ranges of the material the values of critical stress calculated by means of the foregoing equation were in good agreement with the values computed from experimentally determined critical bending moments.

Approximate values of critical stress, as determined by the equivalent slenderness ratio method, were about 20 per cent. lower than the values obtained experimentally, when buckling occurred at stresses near the yield strength of the material.

Values of critical load determined by Southwell plots of the load deflection data were in good agreement with the experimentally determined values of critical load. This agreement demonstrates the applicability of the method to the case of lateral buckling of beams.

Chart for Critical Compressive Strength of Flat Rectangular Plates. (H. N. Hill, N.A.C.A. Tech. Note No. 773, August, 1940.) (86/38 U.S.A.)

The theoretical stress at which a rectangular flat plate will buckle elastically, when uniformly compressed in one direction, can be expressed:—

$$\sigma_{cr}=K\{E/(1-\mu^2)\}(t/b)^2$$

where σ_{cr} = critical stress at which buckling occurs, lb./sq. in.

E = modulus of elasticity of the material, lb./sq. in.

μ = Poisson's ratio for the material.

t = thickness of plates, inches.

b = width of plate, normal to direction of compression, inches.

K = a coefficient depending on the ratio of length to width of the plate (l/b), the conditions of restraint at the edges of the plate, and in some cases on Poisson's ratio.

A chart is now presented for the coefficient K, the curves given applying to various combinations of fixed, simply supported and free edges. The curves demonstrate the importance of the condition of restraint of the loaded edges in determining the buckling stress of rectangular flat plates having L/b ratios less than 3.

Magnesium Alloys in Aircraft. Details of American Practice. (N. E. Woldman, Metal Industry, Vol. 57, No. 24, 13/12/40, pp. 465-8.) (86/40 U.S.A.)

Magnesium alloys can be produced in the following forms:—(i) Castings: sand cast, permanent mould and die cast. (ii) Forgings: hammer and press forgings. (iii) Wrought: extrusions, sheets, plates and bars. The constitution and physical properties of the casting, forging and wrought alloys are discussed. Not all of them are susceptible to heat treatment. The latter, which is a solution treatment, with or without an ageing treatment, produces the optimum physical properties. The solution treatment consists in heating the parts to 650-720°F. for a sufficient time (16-20 hours) until the insoluble constituents go into solution and then air cooling. This treatment increases the strength and ductility to maximum toughness. When followed by ageing for 12-16 hours at 340-400, the tensile

strength and hardness are further increased with a sacrifice in ductility. Magnesium alloys, while possessing good tensile and fatigue properties are very notch-sensitive. Hence notches, scratches, sharp corners must be avoided, also cavities, in which moisture can accumulate and cause corrosion. Electrolytic corrosion in contact with brass and steel is prevented by plating with cadmium. Mg alloys can safely be used at low temperatures, but are not recommended for resistance to wear. Salt water corrosion is prevented by an anti-corrosive treatment known as chrome pickle (Na_2CrO_4 + Conc. HNO_3 + water). This produces a yellow porous coating of chromates which has definite anti-corrosive properties, and at the same time provides a good base for painting.

Non-Destructive Production Tests for Steel Tubing. (Steel, 21/10/40, pp. 38-40 and 75.) (86/39 Great Britain.)

A test for defects in tubing which is entirely independent of the magnetic properties of the tube has been developed by Sperry Products Inc. The detector equipment for production inspection work described in this article is provided with alternative automatic or manual control. An energising coil is employed which induces current in a circular direction in the tube, and a search coil picks out defects. The searching unit output is amplified by electronic equipment and operates visual signals and a motor relay controlling the passage of the tube through the detector.

(Abstract supplied by Research Dept., Metropolitan-Vickers.)

Tests on Lead Bronze Bearings in the D.V.L. Bearing Testing Machine. (G. Fischer, L.F.F., Vol. 16, No. 7, 20/7/39, pp. 370-383. Translation available as N.A.C.A. Tech. Memo., No. 943.) (86/41 Germany.)

The tests were carried out on 12 lead bronze bearings supplied by five manufacturers, the lead content varying between 20 and 40 per cent.

All the bearings had a steel shell backing, the actual bronze deposit (cast on) being about 0.5 mm. thick. Similar tests on light alloy bearing metals are described by the same author in L.F.F., Vol. 16, No. 1, pp. 1-13 (R.T.P. Translation No. 1,092).

The original D.V.L. bearing testing machine is described in an article by O. Heyer (L.F.F., Vol. 14, No. 1, 20/1/37, pp. 14-25). In this machine the bearing rotates about a fixed shaft, whilst a variable load in a fixed direction can be applied to the outside of the bearing by means of an ingenious toggle mechanism. In this way the force distribution over the bearing surface can be made to approach that existing in an engine under load. All the bearings tested were 60 mm. inside diameter, approximately 0.5 mm. thick and the width of running surface 25 mm. The rubbing speed was 5 m./sec. and the temperature of the shaft at a point near the oil film was kept at 120°C. by adjusting the oil circulation. Friction force are not measured by this machine, which is entirely intended to permit rapid examination of the bearing for marks of wear or injury. A safety cut-out device is, however, provided which stops the machine should the power absorbed increase by more than 50 per cent.

Only two of the bearings carried out satisfactorily the specified endurance run of 100 hours at a static load of 250 kg./cm.^{2}. (In these tests the toggle mechanism is clamped.) Apparently running conditions under dynamic load are less onerous, since the oil film can reform itself during the low pressure periods.

It appears that the main difficulty is to ensure a uniform, fine globular lead distribution in the original casting. It is well known that such a desirable grain structure requires a low pouring temperature and fast quenching. Unfortunately this reduces the bonding to the steel shell backing. The use of a high frequency electric furnace for the melting seems to improve grain structure (eddy currents?).

Active research for some alloying component producing the same result has not yet given any satisfactory results and the possibility of fastening the bronze to the steel shell by some alternative method to casting is also receiving attention (A. Blankenfeld, Z. für Metallkunde, Vol. 31, No. 2, 1939, pp. 31-45).

New Equipment for Testing the Fatigue Strength of Riveted and Welded Joints. (W. Müller, Schweizer Archiv, No. 10, 1937. N.A.C.A. Tech. Memo., No. 947, July, 1940.) (86/42 Germany.)

In fatigue testing of joints the stress applied should be sufficient to produce failure within 1-14 days. To obtain a sinusoidal variation in alternating bending stress, the vibrations being in rhythm with the natural frequency of the test body, the simplest method is to form the joint into an oscillating pendulum on which the maximum amplitude is preserved by synchronous application of exciter forces. This has been achieved by attaching the joint by flanges and bolts to a fixed base plate. The upper part of the joint carries a flywheel mass which oscillates during the test and gives a steady motion. The vibration amplitude is maintained by a system of two magnets, operating in opposite phase, which alternately pull two pole pieces downwards. The latter are situated on opposite sides of the pendulum and attached to wires which pull the vibrating part of the joint to left or right. The electric oscillator is operated by two current impulses out of phase by one-half vibration period, produced by rectifier tubes. The arrangement is fully described. The number of vibrations up to failure is determined by a counting mechanism with an automatic stopping device. Tests made on 65 riveted and welded joints indicate that the testing machine can operate without serious disturbance for more than 3,500 hours. Light alloy joints of double U section with an inertia moment of 10.6 cm.^{4} can be maintained at a frequency of 9-11 vibrations per second, and a maximum bending stress of 7-10 kg./mm.^{2} in vibration.

Buckling Tests with a Spar-Rib Grill. (J. Weinhold, L.F.F., Vol. 17, No. 3, 20/3/40, pp. 78-81. Translation available as N.A.C.A. Tech. Memo., No. 950.) (86/43 Germany.)

The author has investigated the buckling loads of grills under certain simple conditions in two previous papers. The present paper deals with a more practical case, the experimental grill having dissimilar spars, 8 mm. wide, 100 mm. deep and 3,250 mm. long. The ribs are eight in number, 7 × 7 mm. and 1,000 mm. long. Both spars and ribs are made of selected pine wood. The loads are applied in the form of equal bending moments at both spar ends, as compression in the line connecting the joints and in the spar centre line as a uniformly distributed spar weight. The evaluation formula is derived from the energy equation as before, allowances being made for the dissimilarity of the spars, the variation in rib rigidity and the load due to spar weight and is valid for a deflection following a half wave.

Comparison with experiment is satisfactory, an effect due to the finite aspect ratio of the test spars is not apparent. For smaller compressive forces and greater end moments the coefficients of the formula should be computed again for further deflection forms in order to find further buckling conditions, which of course yield lower loads at the stability limit.

Improved Type of Radio Sonde. (Inter. Avia., No. 728, 19/9/40, p. 4.) (86/44 Italy.)

An improved type of radio sonde has been taken into operation by the meteorological service of the Italian Air Force about a month ago; the new sondes report

by wireless the temperature, the static pressure and the degree of moisture registered. They are designated "Italia," are used by the "Centrale Assistenza Volo dell'Aeroporto Littorio-Roma" and weigh, including the transmitter, batteries, antenna, etc., 1.44 lb.; they have an average rate of climb of 11 ft./sec. and a ceiling of about 98,000 ft. The temperature measuring range extends over as much as 70 deg. Centigrade; the values measured are transmitted automatically to the ground station every 30 secs.; the range of the transmitter varies from 62 to 125 miles. Upon reception of each signal the ground station checks the position of the sounding balloon which enables a simultaneous determination of wind speed and direction at different altitudes to be made.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.), Ministry of Aircraft Production, and copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

THEORY AND PRACTICE OF WARFARE.

TRANSLATION NUMBER AND AUTHOR.	TITLE AND REFERENCE.
1130 Baasch, H.	*A Contribution to the Question of Estimating the Efficiency of Light Anti-Aircraft Guns with Special Reference to their Gun-laying Devices.* (Flugwehr und-Technik, Vol. 2, No. 8, Aug., 1940, pp. 176-7.)
1133 Grötsch, G. ... ... Plake, E.	*Determination of the Coefficients of Friction of Steel on Steel at High Velocities.* (Z.G.S.S., Vol. 35, No. 1, Jan., 1940, pp. 3-5; No. 2, Feb., 1940, pp. 30-32.) (R.D. Translation No. 898.)

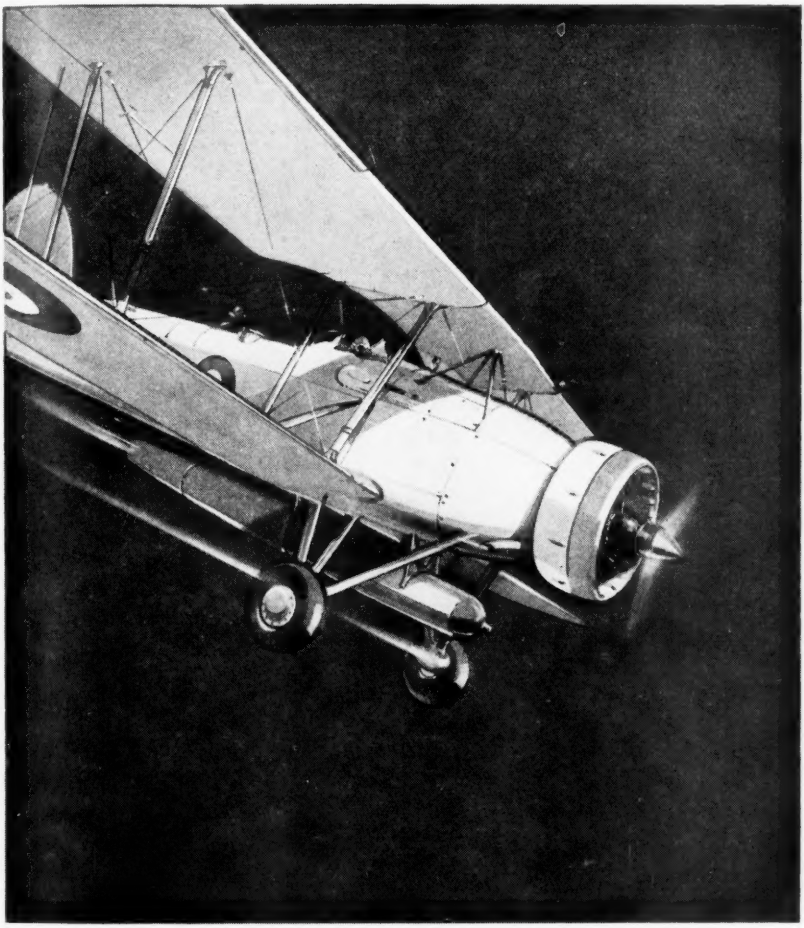
AERO- AND HYDRODYNAMICS.

1115 Ferri, A.	*Some Experimental Results Obtained on Wing Profiles in the Guidonia Supersonic Wind Tunnel.* (Atti di Guidonia, No. 17, 20/9/39.)
1131 Campini, S.	*An Analysis of the Theory of the Campini Jet Propulsion System.* (L'Aerotecnica, Vol. 18, No. 1, Jan., 1938, pp. 18-63.)

MATERIALS.

1128 Sudinin, V. A.... ...	*Wing Vibration in Relation to Engine Masses and Elasticity of the Supports.* (Aeron. Eng., U.S.S.R., Vol. 13, No. 5, May, 1939. pp. 95-7.)

Translation Number and Author.		Title and Reference.
1132	Zeerleder, A. von ...	*Recent Developments in the Riveting of Light Metals in Aircraft Construction.* (Flugwehr und-Technik, Vol. 2, No. 5-6, May-June, 1940, pp. 120-3.)
1134	Hollbach, O.	*Aircraft Materials. A. Steels.* (Deutscher Flugzeugbau, Export Handbook of the German Aircraft Industry, 1939, pp. 173-5.)
		Miscellaneous.
1129	Spetzler, A.	*The Mechanism of Pocket Watches.* (Z.V.D.I., Vol. 84, No. 21, 25/5/40, pp. 355-8.)
1135	Diringshofen, H. von... Hartmann, H.	*The Physiological Effects of CO at High Altitudes.* (L.F.F., Vol. 12, No. 4, 30/7/35, pp. 121-3.)



The FAIREY "Swordfish"

TARANTO 1940

HANDLEY PAGE
"HAMPDEN"

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revenue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.

Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aeron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes.
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A. or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Veroffentlichungen aus dem Gebtete der Nachrichtentecgnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Wind Tunnel Tests of an N.A.C.A. 23021 Aerofoil Equipped with a Slotted Extensible and a Plain Extensible Flap. (T. A. Harris and R. S. Swanson, N.A.C.A. Tech. Note No. 782, November, 1940.) (87/1 U.S.A.)

An investigation has been made in the N.A.C.A. 7 × 10ft. wind tunnel of a large-chord N.A.C.A. 23021 aerofoil equipped with two arrangements of a completely extended 15 per cent. chord extensible flap. One of the flaps had a faired junction without a gap; the other was provided with a slot between the trailing edge of the aerofoil and the nose of the flap. Complete aerodynamic section characteristics are presented for the various flap deflections for both arrangements in the completely extended position.

The results showed that the basic aerofoil gave the lowest profile-drag coefficients over the low lift range; the aerofoil with the plain extensible flap gave the lowest profile-drag coefficients over the high lift range. The aerofoil with the slotted

extensible flap had the same maximum lift at a flap deflection of 25 degrees as the aerofoil with the plain extensible flap had at a flap deflection of 60 degrees. The results of comparisons of the aerofoil pitching moment coefficients obtained with the two types of flap depend upon the basis chosen for comparison.

The Application of Basic Data on Planing Surfaces to the Design of Flying Boat Hulls. (W. S. Diehl, N.A.C.A. Report No. 694, 1940.) (87/2 U.S.A.)

Basic lift data on planing surfaces have been analysed and the data applied to the design of flying boat hulls. It is shown that a balance between air and water forces requires that the beam of the planing area bear a relation to the wing area that is determined by the lift coefficient of the wing and by the angle of dead rise in the planing surface. It is also shown that the fore-and-aft extent of the required planing area depends on the angle of dead rise. Failure to provide sufficient length of planing area appears to be the main reason for the poor water performance sometimes obtained when a large angle of dead rise is used.

Wind Tunnel Investigation of Fuselage Stability in Yaw with Various Arrangements of Fins. (H. P. Hoggard, N.A.C.A. Tech. Note No. 785, Nov., 1940.) (87/3 U.S.A.)

An investigation was made in the 7 × 10ft. wind tunnel to determine the effects of dorsal-type fins and of various arrangements of fins on the aerodynamic characteristics of a streamline circular fuselage. Comparative plots of the aerodynamic characteristics of the fuselage alone and the fuselage with various fin arrangements are given to show their effects on coefficients of yawing moment, drag and lateral force. Results are also given for one case in which a rear fin on a circular fuselage was faired with modelling clay to obtain a fuselage shape with the same side elevation as the fuselage with the unfaired fin, but with an elliptical cross section over the rearward portion of the fuselage.

The results indicated that fin area to the rear of the centre of gravity of the fuselage was beneficial in reducing the magnitude of the unstable yawing moments at large angles of yaw; whereas, fin area forward of the centre of gravity was harmful. The dorsal-type fin was more effective for increasing the yawing stability of the fuselage than was a smoothly faired rearward portion with the same side elevation as the fuselage with the unfaired dorsal-type fin. The minimum drag coefficient and the slope of the curve of yawing moment coefficient of the fuselage at zero yaw were unaffected by the addition of the fins, within the experimental accuracy of the tests.

Stainless Steel for Aircraft Structures. (H. W. Perry, Aircraft Production, Vol. 2, No. 2, Feb., 1940, pp. 35-7.) (87/4 U.S.A.)

Fleetwings Inc. U.S.A. has specialised during the last ten years in the development and production of stainless steel aeroplane wings, control surfaces, fuel tanks and complete amphibian aircraft. Recent products include full cantilever-type wings and control surfaces for Seversky pursuit planes, and wing-tip floats for the Douglas Dolphin seaplane. Also, the Fleetwings Sea Bird amphibian has a basic structure made entirely from stainless steel. Owing to the high strength-weight ratio of steel, the thickness required for equal weight and greater strength of a structure is only one-third that of an aluminium alloy. Full advantage of this can be taken in large structures, such as flying boats, in which the thicker gauges of metal can be used. In smaller craft the minimum thickness is determined by handling qualities and stiffness under compression. The high electrical resistance, low heat conductivity, and hard, clean surface of stainless steel, are particularly advantageous for rapid and economical production by the spot-welding process and for the strength of the joints so made. Since fusion spot-welds add no weight, and those in stainless steel are of small diameter, welds can be made in small outstanding flanges of widths as small as $\frac{1}{8}$in.

Since the very thin gauges in steel sheet have low lateral stiffness, relatively wide flat pitches are avoided by use of corrugated sheet or of channel sections with flanges, welded to flat sheets to produce closed box beams, stringers or stiffeners. The technique developed for employing corrugated sheet in the construction of wings and fuel tanks is described. A special welding technique, employing a machine capable of making 960 spot-welds per minute, has been developed.

Curtiss Propeller Production—including the Hollow Steel Bladed Propeller. (Aviation, Vol. 39, No. 10, Oct., 1940, pp. 42-3, 110-12.) (87/5 U.S.A.)

Each blade is cut in two parts from steel plates tapering in thickness from $\frac{3}{8}$in. to approximately $\frac{1}{16}$in. One section forms the curved part of the blade and the the shank, the other forms the flat or thrust face of the blade. After shaping by means of forming dies, the sections are welded together by the atomic hydrogen method. The welded product is immediately heated to 1,700°F. in the electric furnace to remove welding strains, the hub or shank end is turned, and the blade is rough finished. Heat treatment at 1650°F. and oil quenching are followed by three hours in an electric furnace at 1,000-1,100°F. The final physical properties are as follows:—Elastic limit 125,000 lb./sq. in.; ultimate strength 138,000-154,000 lb./sq. in.; elongation 12-15 per cent.; reduction of area 57-62 per cent.

The hollow construction makes it possible to obtain correct vertical and horizontal balance by application of metal within the blade.

Internal Flow Systems for Aircraft. (F. M. Rogallo, N.A.C.A. Tech. Note No. 777, Oct., 1940.) (87/6 U.S.A.)

An investigation has been made to determine efficient arrangements for an internal flow system of an aircraft when such a system operates by itself or in combination with other flow systems. In addition to a theoretical treatment, some experiments on flat plates and wings provided with inlet and outlet openings were also carried out in the N.A.C.A. 5ft. vertical wind tunnel.

When an internal flow system tends to decrease the final velocity of its wake, the results show that it should be arranged in series with the propulsive system. In this case the inlet should be located at a forward stagnation point, and the outlet opening should be so shaped and located so as to recover the kinetic energy of the jet without increasing the drag of other portions of the aircraft. When an internal flow system tends to increase the final velocity of its wake, as does a propeller, location of the inlet opening in the boundary layer or in the wake of the wing or fuselage may be desirable. A narrow slot inlet opening in a region where the boundary layer is relatively thick appears promising and justifies further investigation.

If the quantity of air required is, however, large, the boundary layer supply will probably be insufficient and a location at the forward stagnation point may be found to be the most efficient.

As regards duct design, the author's recommendations may be briefly summarised as follows:—

(1) High velocities and abrupt changes of shape or area of cross-section must be avoided (except at the outlet).

(2) No throttling devices should be placed within the duct. Regulation at the outlet is practicable and efficient.

(3) Leakage losses must be eliminated at all cost, and all internal flow systems (including cabins) should be tested periodically for tightness.

A Flight Investigation of Exhaust Heat De-icing. (L. A. Rodert and A. R. Jones, N.A.C.A. Tech. Note No. 783, Nov., 1940.) (87/7 U.S.A.)

The National Advisory Committee for Aeronautics has conducted exhaust-heat de-icing tests in flight to provide data needed in the application of this method of

ice prevention. The capacity to extract heat from the exhaust gas for de-icing purposes, the quantity of heat required, and other factors were examined. The results indicate that a wing-heating system employing a spanwise exhaust tube within the leading edge of the wing removed 30 to 35 per cent. of the heat from exhaust gas entering the wing. Data are given from which the heat required for ice prevention can be calculated. Sample calculations have been made on a basis of existing engine power/wing area ratios to show that sufficient heating can be obtained for ice protection on modern transport aeroplanes, provided that uniform distribution of the heat can be secured.

Mechanism of Flutter: A Theoretical and Experimental Investigation of the Flutter Problem. (T. Theodorsen and I. E. Garrick, N.A.C.A. Rept. No. 685, 1940.) (87/8 U.S.A.)

The basic flutter theory devised in 1934, and originally published as N.A.C.A. Report No. 496, is presented in a simpler and more complete form. This paper attempts to facilitate the judgment of flutter problems by a systematic survey of the theoretical effects of the various parameters. A large number of experiments have been conducted in the N.A.C.A. high-speed wind tunnel for the purpose of verifying the theory and studying its adaptability to three-dimensional problems. The experiments included studies on wing taper ratios, nacelles, attached floats and external bracings. General conclusions are as follows:— 1. The two-dimensional theory has been verified within the limits of error in the determination of the primary parameters. 2. The most essential three-dimensional effect is the occurrence of distinct flutter bending modes, which differ from the ordinary vibration modes in that they tend to assume a form which approaches the next higher vibration mode and exhibit a correspondingly higher frequency. The flutter speed is consequently lower than that calculated on the basis of the lowest vibration frequency and the flutter frequency itself is higher. For ordinary damped structures this effect lowers the flutter speed calculated on the basis of the lowest bending mode by only a few per cent. 3. A cantilever wing flutters at a speed calculated by using the constants for the most representative section, situated at about three-quarters of the semi-span. 4. Aspect ratio and structural damping effects tend to increase the flutter speed by a few per cent. above that calculated for infinite aspect ratio and zero internal damping. 5. The effect of mass balancing to bring the centre of gravity forward is essentially as predicted by theory. The effect of nacelles is of lesser importance, but large weights located at some distance away from the wing and attached to it show a very detrimental effect on wing flutter. 6. Wing-aileron experimental studies show that the characteristic flutter range predicted by theory exists and is in substantial agreement with the predicted values.

Structural Tests of a Stainless Steel Wing Panel by Hydrostatic Loading. (R. H. Upson, N.A.C.A. Tech. Note No. 786, Nov., 1940.) (87/9 U.S.A.)

A simplified type of all-metal wing construction of 18-8, spot-welded except for the skin attachment, was tested by means of hydrostatic loading, the wing being proportioned to permit close representation of typical conditions by means of the waterhead.

The general principle of design was to apply the skin on the wing under controlled initial tension and to utilise a finite internal pressure in flight. The initial tensioning was found to be an essential factor and the internal pressure in flight an important factor, although neither was critical with respect to small variations.

The results showed the possibility of eliminating almost all of the stiffeners from a stressed-skin wing, the possible reduction of weight in a lightly loaded wing and of substantial cost in the construction of any all-metal wing. Further

experiments are suggested, however, on the magnitude and the effect of slight surface irregularities, and on the contribution of the complete wing-tip. A discussion of these suggested experiments is not included in the present paper.

With certain recommended improvements, the test method described is believed to be a valuable one for research on any new type of wing construction, particularly in cases where the covering, regardless of material or arrangement, is questionable.

Oscillation of Castoring Wheels. (J. L. Taylor, Aircraft Engineering, Vol. 13, No. 143, Jan., 1941, p. 13.) (87/10 Great Britain.)

Under certain conditions, the nose wheel of a tricycle undercarriage will undergo periodic vibrations (shimmy or wobble) whilst the aircraft is rolling on the ground. It is important that such vibrations should be of small amplitude without requiring excessive damping in the castoring axis. The motion of the wheel is essentially periodic in azimuth, accompanied by a simultaneous periodic translation of the point of contact of the tyre with the ground (*i.e.*, tyre vibrates laterally with regard to the rim). Both tyre and wheel vibrations have the same period, but obviously differ in phase and amplitude. Assuming S.H.M., this can be expressed in the form:

$$\theta = ae^{ikt} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\delta = be^{i(kt+\alpha)} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where θ = wheel deflection in azimuth,

δ = tyre deflection with regard to the rim.

The author investigates the minimum amount of fluid damping required in the castoring axis so as to maintain (a) and (b) constant in (1) and (2).

A number of simplifying assumptions are made, such as:—

(1) Castoring axis is vertical.

(2) Damping torque is proportional to $d\theta/dt$.

(3) Damping of tyre can be neglected.

(4) Fuselage is rigid.

(5) No gyroscopic couples.

From the automatic tracking tendency of the castoring wheel, it can easily be shown that

$$b^2/a^2 = (r^2 + v^2/k^2)$$

where v = forward speed of wheel axis. Taking moments about the castoring axis, the author shows that the fluid damping coefficient $k = v\,I/r$ (where I = moment of inertia of complete wheel unit).

The frequency of the coupled system follows from the equation

$$k^2 = r\,(Er - \mu W)/I$$

where W = vertical load on wheels,

μ = coefficient of friction with the ground.

$E = P/\delta$ where P = side load on tyre.

From a review of the possible effect of factor neglected in the simplifying assumptions, the author concludes that the value obtained for the damping torque is a conservative figure which may safely be used.

Load Factors in Gusts. (F. R. Shanley, U.S. Civil Aeronautics Board, Aircraft Airworthiness Section Rept. No. 7, 1940; reviewed in Flight, Vol. 39, No. 1,676, 6/2/41, pp. 111-2.) (87/11 U.S.A.)

This report, intended principally for pilots, presents the theory of load factors due to gusts in a simplified manner. It is shown that while an aeroplane designed

with a heavier wing loading is more able to resist gust effects than one designed with light wing loading, to reduce stress on an aeroplane it is best to reduce its load when flying in gusty air. Added load factor due to a gust is directly proportional to the aeroplane's airspeed, hence the safety precaution of reducing speed in gusty weather. Research work has been carried out on gusts, and statistics collected from numerous flights to determine the maximum gust velocity likely to be encountered under various conditions of flight. The instrument used for this purpose consists of the accelerometer coupled to the airspeed indicator so that simultaneous readings are obtained on two co-ordinate axes at right angles. The instrument is known as the V-G recorder.

Results obtained during diving tests with the recorder installed in a D.17-S Beechcraft are discussed.

Wing Loading, Icing and Associated Problems of Modern Transport Design. (C. L. Johnson, J. Aeron. Sci., Vol. 8, No. 2, Dec., 1940, pp. 43-54.) (87/12 U.S.A.)

Problems relating to the use of high wing loadings are considered in two broad groups:—

I—Flight Problems: (*a*) Handling characteristics—landing speed, stability, manœuvrability; (*b*) Take-off and climb performance; (*c*) Icing effects; (*d*) Pilot technique.

II—Economic Problems: (*a*) Payload carried; (*b*) Performance gained; (*c*) Initial cost of aircraft; (*d*) Operating costs for given speed; (*e*) Hangar size; servicing problems; (*f*) Crew required.

Conclusions are as follows:—

1. The use of increased wing loading is fully justified on the basis of improved performance, range and economy.

2. Increased wing loading will lead to aircraft with lower first cost and smaller size, both of which have important effects on operating economy.

3. The slight increase in landing speed will not involve a decrease in safety, since stalling characteristics, control, stability and landing gears can be improved.

4. The problem of icing is no more severe for an aircraft with high wing loading than for one with light wing loading. The advantages of higher initial rate of climb, higher speed, etc., still remain with the heavily loaded aeroplane even under severe icing conditions.

5. The icing problem is relatively less severe on large aircraft than on small ones. Current research will lead to substantial improvements in performance under icing conditions.

6. Flight characteristics now common in large aircraft should not be considered as necessarily applying to future designs where changes in safety regulations are considered.

Gas Engine Valves. (S. D. Heron, O. E. Harder and M. R. Nestor, Paper to A.S.T.M., Detroit, March, 1940. Metal Progress, Vol. 37, No. 4, April, 1940, pp. 418 and 456.) (87/13 U.S.A.)

A comprehensive research programme into valve steels included several changes in analysis to improve forgeability and machinability, over 1,000 experimental valves being made and tested in the engine and by new laboratory tests. The best laboratory tests for determining resistance to corrosion by hot exhaust gases are:—(*a*) loss in weight after short immersion in molten lead compounds; (*b*) loss after cyclic heatings and coolings in the gaseous combustion products. The effect of cold corrosion by moisture condensed from exhaust gases can be

duplicated by observing samples after being sprayed daily with engine exhaust condensate. The laboratory test for " hot hardness " is that of mutual indentation of a pair of short cylinders pressed together while hot along a common element of their surfaces. The best temperature is 1,800-1,900°F. Austenitic steels, such as Cr 14, Ni 14, Co 5, Si 0.75, W 2.0 and Mo 0.50 are only moderately hard at atmospheric temperature, but retain this hardness at high temperature. Similar steels containing sufficient Si or Mo to age-harden at 1,600°F. are particularly interesting from the point of view of hot hardness. The above steel is in practically universal use as a valve material. Seating areas have layers of Stellite in America or Brightray (80 per cent. Ni, 20 per cent. Cr) in England. Comparative tests of the two have been inconclusive.

The Maximum Delivery Pressure of Single-Stage Radial Superchargers for Aircraft Engines. (W. von der Nüll, Luftwissen, Vol. 7, No. 5, May, 1940, pp. 174-180. Translation available as N.A.C.A. Tech. Memo. No. 949.) (87/14 Germany.)

The author is of the opinion that the limiting critical altitude of aero engines, both for the present and for some time to come, will be set not by the maximum possible delivery head, but by the temperature rise associated with the compression. However good the fuel, there exists a definite limit to the induction temperature, and unless intercoolers are fitted, it is the compression efficiency, rather than the delivery pressure, that matters. Although intercoolers may become ultimately necessary, it appears that the efficiency of the single-stage has not yet reached its limit, and that by adopting the fully shrouded type investigated by the D.V.L., an improvement in compressive efficiency of the order of 5-10 per cent. should be possible over that attainable with the standard semi-shrouded wheel operating at the same tip speed (300-400 m/sec.).

The author also deduces from test results that supercharger control (at constant speed) will always be more efficient if the throttle is placed at the intake instead of the delivery side of the blower. Both these conclusions are in contradiction with statements by Kollmann, published in a previous issue of this Journal (" Limiting Factors in Single-Stage Centrifugal Superchargers for Aero Engines," K. Kollmann, Luftwissen, Vol. 7, No. 3, March, 1940, pp. 54-61 (R.T.P. Translation No. 1,059), published in Journal of the Royal Aeronautical Society, October, 1940, pp. 775-790). Kollmann is of the opinion that the superiority of the fully shrouded impeller only holds in the region of relatively low tip speeds (~200 m/sec.) and that in the interesting range of 300-400 m/sec. there is nothing to choose between the semi-shrouded and the completely shrouded impeller. As the latter is much more difficult to manufacture, its adoption could thus be justified only in special cases (multi-stage wheels?).

As regards throttle control, Kollmann states that position of the throttle on the delivery side facilitates automatic control and can be made fully as efficient as the more normal intake throttle.

For a more detailed account of von der Nüll's researches at the D.V.L., see R.T.P. Translation No. 517 and 517A entitled " The Design of Aero Engine Superchargers."

Determination of Free Oscillation Frequency of Turbine Blades. (I. K. Chernishevskiy, Sov. Kotloturbo, No. 8, 1940, pp. 269-73.) (87/15 U.S.S.R.)

The author deals with various factors influencing blade frequency, which are not taken into consideration by methods of calculation for determining such frequency, and also with the question of empirical correction factors, and the possible value of the distinction between calculated and actual frequencies. He

considers that the system of correction factors should be determined by the united experimental efforts of all Soviet Union turbine works and scientific research institutes. He points out that with a rational system of empirical correction factors as above-mentioned, the tolerance in determining the actual frequency of the blade on the wheel will be dependent on the relative calculation error; variations in blade frequency characteristics in course of manufacture; frequency variation dependent on the varying force of clamping of the blade in the rim of the wheel. Illustrated with eight diagrams and one photograph.

(Abstract supplied by Research Dept., Metropolitan-Vickers.)

Problem of Valve-Stem and Valve-Head Deposits. (A. T. Colwell, J.S.A.E., Vol. 47, No. 3, Sept., 1940, pp. 358-65.) (87/16 U.S.A.)

Deposits on valve stems to-day are causing about 50 per cent. of the valve trouble in the automotive field, and slightly more than 50 per cent. in the aircraft field. Although much work has been done on varnish and lacquer deposits, most of it has applied to pistons and rings, with valves receiving only passing interest.

Valve deposits are divided into six classifications: those on the valve head; the hard, flint-like deposit from operation; varnish on the stem; deposits under the head and on the stem at the valve-head end of the guide formed by shuttle driving; deposits on intake valves; and deposits on valve seats.

The fact that any oil will oxidise or decompose at some temperature found along the valve stem makes a complete solution of the build-up problem most difficult. It has been definitely proved that oils with good oxidation resistance at high temperatures cause the least trouble. The design problem, therefore, is to attempt to get a valve-stem temperature at the top of the guide which will not cause oil decomposition, or to meter the oil so that the deposit formed is not thick enough to cause trouble between overhauls; or to remove the deposit in some way as it is formed.

Comparing automotive and aircraft remedies, the automotive status is more confusing because operating conditions vary far more. A number of aircraft and automotive remedies for preventing valve deposits are discussed.

48 *Ordinate Harmonic Analysis and the Harmonic Spectrum of Two-Cycle Diesel Torque.* (N. Klock, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 158-60.) (87/17 U.S.A.)

For the harmonic analysis of periodic curves, machines as well as numerical methods are available. The machines are expensive and not generally available, and time is required to learn their operation. Therefore, an occasional analysis of a curve consumes even less time by the numerical method than by the machine. The best-known numerical method is that of Runge described in many places—a good account is found in Scarborough's book. The principle is clear, but writers usually give the method for 6, 12 or 24 ordinates for the sake of simplicity, which is not sufficiently accurate for most applications. In this paper the 48-ordinate scheme is fully given in Tables 1, 2 and 3.

For the analysis of torsional vibrations the harmonic content of the torque curve of the disturbing engine is required. Such analyses have been published for the four-cycle Diesel engine and for the four-cycle gasoline engine for aviation purposes. But to the author's knowledge none has been published for the two-cycle Diesel engine. Such a spectrum is given herein.

Turbine Blade Vibration Due to Partial Admission. (R. P. Kroon, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 161-5.) (87/18 U.S.A.)

This paper deals with stresses in steam-turbine blades set up during partial admission—that is, when the steam loading on the blades is intermittent. By

making simplifying assumptions about the character of the loading, it is possible to develop simple relations showing how the blade stress depends on frequency, running speed and damping. Apparatus to determine experimentally the damping of blade steels and optical equipment to investigate the exact nature of the steam forces acting on the blades in actual operation are described.

Generally speaking, the damping increases with the stress, and decreases with frequency and temperature. In the normal working range, the 12 per cent. Cr steel has about ten times as much damping as the Cr-Ni steels.

Piston Temperatures in an Air-Cooled Engine for Various Operating Conditions. (E. J. Manganiello, N.A.C.A. Report No. 698, 1940.) (87/19 U.S.A.)

As part of a programme for the study of piston cooling, tests were conducted on a single-cylinder, air-cooled, carburettor engine to determine the effect of engine operating conditions on the temperature at five locations on the piston.

Indicated mean effective pressure, engine speed, fuel-air ratio, spark timing, cylinder temperature, oil temperature and oil viscosity were each separately varied, the other conditions being held constant. The tests showed that the piston temperatures increased with indicated horse-power, the variation being slightly greater for a change in indicated horse-power obtained by varying the indicated mean effective pressure than for that obtained by increasing the speed. The piston temperatures varied linearly with cylinder temperature, increasing about 0.66°F. per degree Fahrenheit rise in wall temperature; increased rapidly with increased spark advance; and increased as the mixture was enriched to a fuel-air ratio of about 0.077, decreasing with further enriching. Decreased oil viscosity resulted in a slight decrease of piston temperatures. Piston temperatures slightly decreased with an initial increase in oil (out) temperature, and started increasing with a continued rise in oil temperature. A rough test indicated that the crankcase air and the oil thrown off from the bearings provide a small amount of piston cooling.

Factors Affecting Heat Transfer in the Internal Combustion Engine. (P. M. Ku, N.A.C.A. Tech. Note No. 787, Dec., 1940.) (87/20 U.S.A.)

A method was developed for the direct measurement of the average heat-transfer coefficient from the gases in the cylinder during the cycle of operations of an internal-combustion engine. Experimental measurements were made with a heat collector projecting through a spark-plug hole into the combustion chamber of the test engine, in order to examine the effects of several engine-operating and design parameters on the mean heat transfer to the collector.

For an engine of a fixed compression ratio and valve timing, operating with a given mixture ratio, with ignition adjusted to give maximum pressure at the same crank-angle position, the mean heat transfer was found to be a function of the air consumption only, no matter what changes the volumetric efficiency, inlet-air density or mean piston speed might undergo. The heat transfer was found to vary with the 0.5 power of air consumption in both a slow-speed and a high-speed C.F.R. engine. This figure was surprisingly constant for all tests.

The effect of the heat-resistive coating formed by the combustion deposits on the surface of the heat collector was also examined. Starting with a clean heat collector, the heat transfer fell about 20 per cent. during the first fifteen hours of operation, after which it fell off at a very slow rate, becoming constant after about forty hours of operation.

Measurements on Detonation in the Duchêne Apparatus. (G. Broersma, J. Aeron. Sci., Vol. 8, No. 2, Dec., 1940, pp. 62-72.) (87/21 Holland.)

Investigations have been made in the Duchêne apparatus (Publ. Sci. et Tech. du Ministère de l'Air, No. 11, 1932) as to whether the mechanism of detonation

obtained with this apparatus differs from that obtained with the " Delft " window engine (Boerlage, Broeze, Van Driel and Peletier, " Engineering," March 5th, 1937). The Duchêne apparatus consists of a steel cylinder with piston (bore 50 mm., stroke 295 mm.), the combustion chamber being bored from the same block of steel at the end of the cylinder. A sparking plug closes the opposite end of the combustion chamber. Flame photographs are taken through a small glass window running the entire length of the explosion chamber. In the present experiments fuel was introduced through a glass carburettor. The results obtained consisted of flame pictures, pressure diagrams and ionisation diagrams. They indicate that there are two mechanisms of detonation:—(*a*) Physical detonation produced by physical processes of aerodynamic flow, mixing and diffusion. A critical state is reached at which the speed of the flame front changes from the subsonic to a supersonic rate. (*b*) Chemical detonation in which the chemical chain reactions in the end gases produce a critical state in which the end gas ignites at one or more points. From these points combustion proceeds at normal subsonic speeds. Each combustion mechanism has its own time constant depending upon thermodynamic, chemical and geometrical considerations. They may overlap. Thus, when chemical detonation has started, physical detonation may still occur, but not conversely. Both of these mechanisms may occur in the Duchêne apparatus. In the " Delft " window engine chemical detonation is usual, as in most engines. In tubes and bombs physical detonation usually occurs.

Fuel Economy in Petrol Engines. (W. T. David and A. S. Leah, J. Inst. Mech. Eng., Vol. 143, No. 5, Oct., 1940, pp. 289-312. J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, pp. 29-30A.) (87/22 U.S.A.)

Data are supplied from which may be estimated the possible margin of improvement in performance for any given engine in practice. Part I gives charts for indicated thermal efficiency, fuel consumption per I.H.P. hour, and I.M.E.P. attainable in a compact engine of any bore between 3 and 8 in. for compression ratios between 4:1 and 9:1, speeds from 1,000 r.p.m. upwards, and mixture strengths between 20 per cent. weak and 20 per cent. rich. Separate charts are given for octane, ethyl alcohol and benzene. The charts are based on accurate values of the gaseous internal energies, entropies and dissociation constants, allowances being made for heat losses during explosion and expansion, using heat-loss estimates deduced from closed-vessel explosion experiments and single-cylinder test results. Part II discusses phenomena associated with the working fluid and combustion of the charge, including turbulence and its effect on heat loss during explosion and expansion, the delay period after ignition, incomplete combusiton at the peak pressure and after-burning. In an engine of 4.5 in. bore running at 1,500 r.p.m., the heat loss would be about 1 per cent. (of the heat of combustion) during explosion, and about 5 per cent. during expansion. Under detonating conditions the rate of heat loss is greatly increased, mainly due to increased turbulence. Part III discusses actual engine performance compared with attainable performance. Apart from distribution difficulties in multi-cylinder engines, it is believed that improvement in charge-mixing within each cylinder would be one of the main directions in which progress could be made.

Curtiss-Wright Built-in Engine Torque Indicator. (Inter. Avia., No. 739, 12/12/40, p. 9.) (87/23 U.S.A.)

The Curtiss-Wright Corporation is now conducting its test flights, using built-in torque indicators, which serve for accurate supervision of the engine's power output to the airscrew in flight, and enable a correspondingly accurate calculation of the test results. The indicator installed on the Double Row Cyclone 14-cylinder engine consists of a torque arm mounted in front of the reduction gear system

in the front portion of the crankcase; this arm transmits the reaction forces exerted by the revolving airscrew boss on the stationary parts of the sun gear to a balancing valve which is free to move to and fro. The latter, together with an oil booster pump, is mounted in a casing on the top of the front of the engine casing. The pressure required of the pump to maintain the balancing valve in the central position is controlled automatically and represents a direct measure of the engine torque. Thus the device enables the actual engine output to be determined during flight under all flying conditions and at all throttle positions. The principle is the same as that of the torque indicator developed by Pratt and Whitney some time ago.

On the Mechanism of Boundary Lubrication. I. The Action of Long Chain Polar Compounds. (O. Beeck, J. W. Givens and A. E. Smith, Proc. Roy. Soc., Vol. 177, No. 968, 31/12/40, pp. 90-102.) (87/24 U.S.A.)

The effect of long-chain polar compounds on the coefficient of kinetic friction under boundary conditions has been studied, using the Boerlage four-ball friction apparatus in various modifications. With steel balls of the highest grade, coefficients of friction for a great number of lubricants were measured as a function of the relative velocity of the rubbing surfaces.

The structure of thin films of these lubricants rubbed on polished mild steel surfaces was investigated by electron diffraction.

It was found that the lubricants showing little or no surface orientation had a constant coefficient of friction of about 0.1 over the available velocity range from 0 to 1 cm/sec. With oils which showed high surface orientation imparted by addition of long-chain polar compounds, a sudden decrease of the coefficient of the friction was observed at various velocities of the sliding surfaces, depending upon the compound used. Investigation of a great number of compounds gave a direct correlation of this effect with molecular orientation: those compounds causing the effect to occur at the lowest velocities were found to be most highly oriented with their carbon chains most nearly perpendicular to the surface. Since such a change of the coefficient of friction can only be explained by the wedging of oil under the surface (oil drag), the effect was termed the "wedging effect" leading to a type of lubrication which may be called "quasi-hydrodynamic."

By measuring the electrical resistance between the sliding surfaces it was found that the regions of sudden decrease of the coefficient of friction correspond to a change from metallic contact to extremely high resistance.

The investigation shows that long-chain polar compounds act primarily by inducing the "wedging effect" and not by giving a direct protection to the surface.

On the Mechanism of Boundary Lubrication. II. Wear Prevention by Addition Agents. (O. Beeck, J. W. Givens and E. C. Williams, Proc. Roy. Soc., Vol. 177, No. 968, 31/12/40, pp. 103-118.) (87/25 U.S.A.)

If two metal surfaces slide over each other in the presence of a lubricant and under high load, high pressures and temperatures prevail at those isolated spots which actually carry the load, leading to wear and possibly to breakdown.

The action of wear-preventing agents under these conditions has been studied in detail, and it has been found that such agents are effective through their chemical polishing action, by which the load becomes distributed over a larger surface and local pressures and temperatures are decreased. Especially effective are compounds containing phosphorus or other elements of group V of the periodic system. These have been found to form a metal phosphide or homolog on the surface which is able to alloy with the metal surface, lowering its melting-point markedly, and by this action aiding greatly in maintaining a polish.

The wear experiments were carried out with a highly sensitive and accurate method which used metal-plated steel balls as its sliding elements. Under the experimental conditions additions of 1.5 per cent. triphenyl phosphine or triphenyl arsine in white oil gave wear-prevention factors of 7.2 and 12.2 respectively (relative to pure white oil). A further addition of 1 per cent. of a long-chain polar compound is able to double the wear-prevention factor obtained with the polishing agents, and wear-prevention factors as high as 17.6 have been observed. The specifically physical action of the long-chain polar compounds is discussed in the preceding paper.

Study of Monolayers of Some Esters and Chlorinated Derivatives Possibly Useful as Lubricating Addition Agents. (G. L. Clark and J. V. Robinson, J. Amer. Chem. Soc., Vol. 62, 1940, pp. 1948-51. J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 25A.) (87/26 U.S.A.)

An investigation into the mechanism of the action of polar organic compounds added to lubricating oil to increase its oiliness is based on the theory that the addition agent is absorbed on the metal, acting as a buffer between metal surfaces. X-ray diffraction has been used previously to show that such an absorption actually takes place, and in the present work the monomolecular film balance was selected to furnish quantitative data on the strength of absorption and the nature of the molecular packing of materials used as oiliness agents. The collapse pressure of monomolecular films measured on the hydrophil balance may possibly be correlated with the resistance to shear of the same substances on a metal surface in an engine bearing. It is suggested that a surface consisting of a close-packed array of hydrogen atoms attached to hydrocarbon chains should offer the minimum resistance to the hydrocarbon molecules of a lubricating oil slipping over it. Using an improved film balance under carefully controlled conditions, measurements are made of area per molecule and collapse pressure on water surfaces for monolayers of certain esters which have possible use as addition agents in lubricating oils, namely, Methyl Stearate, " L," Chlorostearate, Dichlorostearate, Oleate, Ricinoleate, and Chlororicinoleate; Ethylene Glycol Distearate and Ricinoleate and Tricresyl Phosphate.

Fiberglas. New Basic Raw Material. (G. Slayter, Ind. and Eng. Chem. (Industrial Ed.), Vol. 32, No. 12, 2/12/40, pp. 1,568-71.) (87/28 U.S.A.)

Glass fibres possess desirable properties not found in any other commercially available material. They are produced either as a wool-like fibre, largely used for thermal insulation, or as a textile fibre, employed to form yarns, threads and woven fabrics. Glass fibres are incombustible, non-absorptive, chemically stable and resistant, unattacked by fungus or vermin, and they possess extraordinary tensile strength, electrical properties and heat resistance. Their production, properties and uses are described.

The wool forms are used for insulation of houses, ships, trains, aircraft, etc., and for industrial insulation at temperatures from below 0° to over 1,000°F. Textile forms are used for electrical insulation, electrical storage battery retainer mats, chemical-and-fume filtration, etc.

Plane Braced Frames Loaded Perpendicularly to their Planes. A New Application of Cross' Method. (J. Drymael, J. Roy. Aer. Soc., Vol. 44, No. 359, Nov., 1940, pp. 827-43.) (87/27 Belgium.)

The article deals with the calculation of plane frames, each bar of which is able to withstand flexion perpendicularly to the main plane. After having shown that the stress corresponding to the loads parallel to that plane is independent of the

stress corresponding to the perpendicular loads, the author develops for this latter a method of resolution based on Cross' principle. Fictitious supports are added to each knot and then successively removed, till the structure reaches the true form corresponding to the loading. A very important improvement of the original method—formerly not applied to a three-dimensional construction—consists in the use of adjustments—that is, appropriate movements of parts of the structure as a whole.

The method proved to have many advantages: difficulties independent of the degree of redundancy, no loss of accuracy between the beginning and the end of calculations, large number of verifications in the course of resolution, reliability of the results, easy understanding of the successive steps, possibility of simultaneous work for many contributors, and relative shortness of the amount of work required.

Rating of Aircraft Quality Steels. (J. B. Johnson, Metal Progress, Vol. 8, No. 4, Oct., 1940, pp. 382-3.) (87/29 U.S.A.)

The Aeronautical Materials Specifications published by the S.A.E. incorporate requirements for chemical composition, grain size, physical properties and surface condition, with the additional provision that the material must be "aircraft quality," *i.e.*, the finished parts must be tested by magnetic inspection. The only practicable process is the Magnaflux process, which will indicate any non-homogeneity in and just below the surface. Its most useful application is for detecting non-metallic inclusion, on the basis of which aircraft steel is accepted or rejected. The term "aircraft quality" does not necessarily have the same significance for all aircraft parts, since in some parts inclusions may be tolerated in low-stressed sections, while rigorously excluded from highly-stressed sections. Thus piston pins require a steel practically free from any non-metallic inclusions. At present there is no established standard for the rating of Magnaflux inspections, but one is now in course of preparation by the S.A.E.

Stress Distribution in, and Equivalent Width of Flanges of, Wide, Thin-Wall Steel Beams. (G. Winter, N.A.C.A. Tech. Note No. 784, Nov., 1940.) (87/30 U.S.A.)

The use of different forms of wide-flange, thin-wall steel beams is becoming increasingly widespread. Part of the information necessary for a rational design of such members is the knowledge of the stress distribution in, and the equivalent width of, the flanges of such beams.

The primary purpose of the investigation was to analyse the stress distribution in the flanges of wide, thin-wall beams of I-, T-, U- and box shape, and to obtain results suitable for direct application in design. It is shown that the magnitude of the bending stresses in the flanges of such beams varies across the width of the section, and that the amount of this variation depends upon the dimensions of the beam and upon the type of loading.

Therefore, in the determination of the magnitude of the maximum bending stress in design work, the equivalent width of such flanges should be used instead of the actual width. Curves are given from which this equivalent width can be read directly for any particular type of beam and loading.

For the purpose of facilitating the experimental verification of the analytical results, further curves have been computed that give the ratios of the maximum to the minimum bending stress in the flanges. These ratios have been checked experimentally by means of strain measurements on eleven I-beams. The experimental data confirm very satisfactorily the analytical results.

It is further shown that the cross-sections of wide beams made of extremely thin sheets are subject to distortion that gives rise to additional stress concen-

tration. Equations are given furnishing simple conditions for determining the limiting dimensions of beams for which the effect of this distortion may be neglected in practical applications. It may easily be verified numerically that practically all beams of structurally possible dimensions will satisfy these conditions.

The Impact of a Mass Striking a Beam. (E. H. Lee, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 129-138.) (87-31 U.S.A.)

In the first part of this paper a concise approximate solution is developed, making the assumptions that the duration of contact is small in comparison with the period of the fundamental mode of vibration of the beam, and that only the fundamental mode of oscillation of the beam need be considered. Results obtained by this method are checked against those determined by the lengthier numerical method. Good agreement is reached in some examples, but other results show large errors, both in the contact compression force and in the resulting motion.

Light was brought to bear on this difficulty by using a solution based on energy and momentum considerations, giving a curve which supplies a rapid determination of the distribution of energy among the various modes of vibration of the beam. This curve gives directly the condition for the vibrational energy developed in the beam, due to the impact, to be confined mainly to the fundamental mode. This is shown by examples to be the required condition for the validity of the previous approximate method.

The solution using energy and momentum considerations is developed to give the motions of the beam and mass resulting from the impact (free vibrations in the beam and uniform velocity of the mass) so that the subsequent development of the impact can be ascertained and repeated impacts dealt with. The investigation also gives the deflection curves of the beam produced by the impact; these show a wide deviation from static-deflection curves.

Immediately after contact has ceased, the deflection is limited mainly to the central portion of the beam; near the supports the deflection is small and in the opposite direction. Later, the first mode of vibration dominates.

For simplicity, this paper has dealt solely with central impact on a beam simply supported at its ends. No difficulties are encountered in generalising the method for impact at any point along a beam which is supported in any way. This general theory is developed briefly in Appendix 1, the procedure being identical with that adopted for the specialised problem.

The Orthogonally Stiffened Plate Under Uniform Lateral Load. (H. A. Schade, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 143-146.) (87/33 U.S.A.)

The problem here discussed may be described as follows:—A rectangular grid of orthogonally intersecting beams rests on rigid supports on all four edges. The grid may be plated on one or both of its surfaces and supports a uniformly distributed lateral load. On two parallel edges, termed the " transverse edges," the beams are fixed. On the other two edges, termed the " longitudinal edges," the beams are freely supported. The beams in the longitudinal system are all identical and equally spaced, except the central longitudinal beam, which may be stiffer than the others in the system. The beams in the transverse system are all identical and equally spaced, but their size and spacing are not necessarily the same as in the other direction.

The problem of deflection under a uniform lateral load was solved in previous papers (Proc. Int. Congress of Applied Mechanics, 1938, p. 140), approximately by means of the infinite-strip method, whereby the solution for a strip of such stiffened plating, infinitely long, freely supported on the edges, an with a single transverse support, was obtained. The solution for the single transverse support

was then simply superimposed upon the solution for another such transverse support, which gave an approximation to the solution for the plate included between two such transverse supports. In the previous papers this method of solution was applied to the double-bottom structure of a ship. It is equally applicable to deck structure and many other elements of a ship, and also to many aeroplane structural problems. Under certain conditions, where the side ratio—that is, the ratio of the longitudinal dimension to the transverse dimension—is small, the approximate solution is inadequate; consequently, the following exact solution, applicable to all side ratios, has been developed. It follows, in general, the method used by Huber for the orthotropic plate.

Analysis of Clamped Rectangular Plates. (D. Young, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 139-142.) (87/32 U.S.A.)

The bending of rectangular plates which are clamped at all four edges and subjected to the action of lateral loads is a problem which has received considerable attention because of its technical importance. Two main methods of attack have been used for obtaining solutions, namely, (*a*) Ritz's energy method, a recent discussion of which has been given by G. Pickett, and (*b*) the superposition method proposed by S. P. Timoshenko as a generalisation of Hencky's solution. These methods are approximate in the rigorous mathematical sense, but, practically, the results may be obtained to any desired degree of accuracy by taking sufficient terms in the infinite series of simultaneous equations which occur in both these methods. To date, complete analyses are available only for the case of a uniform load, and for the case of a central concentrated load. In this paper Timoshenko's method is applied to a number of loadings which have not been treated before.

For the plates treated in this paper it is assumed that all four edges are perfectly fixed, so there is no deflection or change in slope at the edges under the action of the lateral loads.

Some Observations on the Theory of Contact Pressures. (S. Way, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 147-157.) (87/34 U.S.A.)

Some of the observations that can be made regarding stresses and displacements in a semi-infinite elastic solid with given normal surface loading are briefly as follows:—

(*a*) There are a number of cases in which an infinite number of different load distributions inside a region R of the surface produce the same system of stresses and horizontal displacements in the surface outside R.

(*b*) The horizontal displacements in the surface are shown to stand in a simple proportionality relation to the slopes in the x and y directions of a stretched membrane loaded in the same way as the elastic solid. The stresses in the surface are related to the second derivatives of the membrane deflection.

(*c*) An analogy can be set up between the stresses in the surface of the semi-infinite solid, when it carries a loading $q=f(x)$ along a line segment from $x=-c$, $y=0$ to $x=c$, $y=0$, and the shearing stresses on certain planes in a semi-infinite solid in a plane state of strain loaded by the pressure distribution $p=f(x)$ along the band between $x=-c$ and $x=+c$. The same analogy also holds when the latter body is a thin sheet in a state of plane stress.

Convergence of Hardy Cross's Balancing Process. (R. Oldenburger, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 166-170.) (87/35 U.S.A.)

Hardy Cross has introduced a process of structural analysis by balancing moments against each other in successive steps, this process being part of an

infinite procedure. It has been used by many engineers, as for example by Grinter. Southwell has given an equivalent method, the convergence of which was considered in a paper by Temple. Using energy considerations, Temple gave two convergent methods of applying the Southwell process to a given structure.

One can easily show that the Cross method may be applied to a given structure in such a manner that the process does not converge. In the present paper the author gives necessary and sufficient conditions for the convergence of the Cross method, and exhibits a convergent process of balancing any given structure. In particular, he shows that a balancing process P can be described by real linear transformation—that is, by a matrix composed of real numbers, and that the process P converges in the sense of this paper if, and only if, the infinite power of this matrix exists and is zero. The existence and vanishing of the infinite power of a real matrix has been treated elsewhere. For a discussion of matrices and their applications, the reader is referred to a book by Frazer, Duncan and Collar.

The study in this paper is restricted to a continuous beam. The argument for a network of beams is similar to that given here.

Strength of Spot Welds. (Neuman and McCreery, Weld. Engr., Dec., 1940, pp. 28-31 and 42.) (87/36 Great Britain.)

Investigations have been carried out by the authors on the strength determination of spot-welded joints. Such joints are found to be similar in many respects to riveted joints, but can carry more load. Resistance welding, with button electrodes, was used on the test pieces, attention being paid to correct pressure and timing. Certain conclusions are drawn from the data given, regarding the design of spot-welded joints and the factor of safety to be employed.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Reports of Investigations on Selected Types of High Tensile Steels. (Reeve, Trans. Inst. Welding, Oct., 1940, pp. 177-202.) (87/37 Great Britain.)

This report gives details of tests carried out by a Sub-Committee on the Weldability of High Tensile Structural Steels. After chemical analyses of the eleven steels used, there are tensile, bend and impact test results for unwelded and butt-welded specimens. Data is also drawn from Reeve crack tests and quench-hardening tests made on $\frac{1}{2}$in. and 1in. plate. Conclusions drawn from the work are discussed.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Selection and Welding of Low Alloy Structural Steels. (Dearden and O'Neill, Trans. Inst. Welding, Oct., 1940, pp. 203-214.) (87/38 Great Britain.)

A discussion is given on the effect of alloying elements on the tensile properties and hardenability of steel. An examination is made of factors causing decreased weldability, and precautions to be taken during metallic arc welding to prevent cracking are also considered. Empirical expressions are given by the authors for calculating the yield strength, maximum stress and weld-hardening of structural steels from their chemical composition.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Aluminium Casting Alloys for Internal Combustion Engines. (Engineering, Vol. 151, No. 3,917, 7/2/41, p. 120.) (87/39 Great Britain.)

Two publications issued by Messrs. Aluminium Union Ltd. describe recent developments in Al-alloys for internal-combustion engines. These include a piston alloy containing 10 per cent. Cu, with small additions of Fe and Mg. It is easier to machine and cheaper than the material previously used, containing 4 per cent. Cu, 2 per cent. Ni, and 1.5 per cent. Mg. Both alloys are used in the heat-treated condition and are stable and mechanically strong at temperatures up to 400°C.

Amongst the corrosion-resistant magnesium-aluminium casting alloys, one containing 1 per cent. Mg is amenable to heat-treatment and is suitable for sand and gravity die castings of simpler forms. An alloy containing 4 per cent. Mg is employed in the as-cast condition for carburettor bodies. There is now a tendency to replace the wrought components of internal-combustion engines by castings in alloys giving the required mechanical properties. An example is an alloy containing 4-5 per cent. Cu, up to 0.9 per cent. Si, up to 0.7 per cent. Fe and 0.25 Ti, which after heat-treatment has an ultimate tensile strength of 26 tons/sq. in.

Titanium and Some Properties of Cr-Mo Steel for Aeroplane Tubing. (G. F. Comstock, Metals and Alloys, July, 1940, pp. 21-6.) (87/40 U.S.A.)

In these forged and normalised S.A.E. X 4130 steels, welded lengthwise, machined flat and bent cold with the weld outside, the presence of titanium improved the bending quality even when accompanied by higher manganese or 0.31 per cent. Cu. Steels with 0.15 per cent. Ti and with 0.09 per cent. Ti and 0.31 per cent. Cu bent most easily after welding, without cracking. Presence of over 0.1 per cent. Ti in these samples produced a softer steel, but did not decrease the degree of hardening by welding. With 0.85 per cent. Mn and 0.093 per cent. Ti the steel was harder than with the normal manganese content, but there was no greater hardening by welding than in the untreated steel. The microstructure showed a narrower hardened and coarsened zone in the titanium steels than in the untreated, especially without copper or increased manganese.

Improved ductility, impact value and microstructure produced by titanium or Ti + Al in the normalised test-bars is reflected by a similar improvement in the weld-bend tests. With the manganese increased to about 0.85 per cent. and 0.09-0.10 per cent. Ti in this S.A.E. X 4130 steel, the strength in the normalised condition is satisfactory, the hardening by welding is not excessive, and the ductility after welding and resistance to impact are definitely improved as compared with the regular or untreated X 4130 steel. The investigation is described and results of welding tests are summarised.

The Chemical Exploration of the Stratosphere. (F. A. Paneth, Chemistry and Industry, Vol. 60, No. 1, 4/1/41, pp. 8-9.) (87/42 Great Britain.)

The sampling is carried out by sounding balloons, some of which have reached altitudes of more than 30 km.

It appears from the results of analyses subsequently carried out on the ground that at altitudes above 20 km. the He content of the air increases, while the O_2 content decreases. This seems to indicate the absence of wind and the consequent separation of the gases according to their density.

Blast Tests on Glass. (Plastics, Vol. 5, No. 45, Feb., 1941, pp. 23-5.) (87/41 Great Britain.)

A laboratory apparatus has been devised in which glass can be subjected to the same degree of blast in various tests. The apparatus consists of a Celastoid vacuum chamber connected through a gate valve to a reserve vacuum chamber, and thence to a vacuum pump. The glass under test, coated with anti-shatter material, forms the base plate closing the mouth of the Celastoid jar. With the gate valve closed, air is pumped out of the reserve vacuum chamber until a negative pressure of 20 inches of mercury is obtained. The gate valve is then opened quickly, sudden partial vacuum is formed, and the glass breaks. The value of the anti-shatter material with which it has been treated is assessed from the number and velocity of the flying fragments. Results obtained with adhesive tapes and textile netting show that the area of glass covered must exceed 50 per cent., as below this figure a dangerously high percentage of the glass flies. Viscose film affords good protection, but is difficult to apply. Anti-shatter lacquers have an estimated useful life of only three months.

On the Right- and Left-Handedness of Quartz and its Relation to Elastic and Other Properties. (K. S. Van Dyke, Proc. I.R.E., Vol. 28, No. 9, Sept., 1940, pp. 399-406.) (87/43 U.S.A.)

The confusion concerning the elastic properties of quartz which exists in the literature of the Piezo-electric resonator is pointed out. Emphasis is placed on the accepted definitions of right and left quartz and of right- and left-handed optical rotation, the disregard of which by authors, together with a rather free use of axial systems of their own choosing, sometimes obscurely defined, is responsible for the confusion.

An independent experimental investigation is made of the interrelations between Piezo-electric polarisation, optical rotatory power, elastic compressional compliance, and characteristic etch markings, and thereby with the natural face forms of the quartz.

Particular care is taken to avoid any possible errorss in sign in relating these properties, and a number of such errors in the literature are pointed out.

The etch pattern on a quartz sphere is described, as well as its use as a reference standard in determining the orientation of quartz resonators by means of the etch patterns on their faces.

Electrical Transmission of Flow and Level Records. (Linford, B.E.A.M.A. J., Dec., 1940, pp. 97-101.) (87/45 Great Britain.)

Principles involved in the use of electrical circuits for the remote recording of fluid levels, rates of flow, pressures, etc., are explained. Any of three ways may be used to transform the mechanical function into an electric one. A float movement may operate the contact arm of a resistance, affecting the flow of current in a circuit, or may be made to influence an inductance bridge, or send impulses along line wires to a receiver. Some circuits of general character employing these methods are described. The article is to be continued.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Field Strength of Motor Car Ignition Between 40 and 450 Megacycles. (R. W. George, Proc. I.R.E., Vol. 28, No. 9, Sept., 1940, pp. 409-12.) (87/44 U.S.A.)

Measurements of motor-car ignition peak field strength were made on frequencies of 40, 60, 100, 140, 180, 240 and 450 megacycles. Propagation was over Long Island ground, and the receiving antennas were 35 feet high and 100 feet from the road. Under these conditions, the average field strength varied about 2 to 1 over the frequency range. Curves show the maximum field strength versus frequency for 90, 50 and 10 per cent. of all the measurements. Vertical and horizontal polarisation are compared, showing slightly greater field strength, in general, for vertical polarisation. New cars, old cars and trucks are compared, showing no large differences of ignition field strength.

Some of the factors involved in motor-car ignition radiation are mentioned. Theoretical propagation curves are included and the measuring system is briefly discussed. Although these data are not comprehensive of the subject, they do show that appreciable motor-car ignition interference can be expected at frequencies up to 450 megacycles.

There are several factors which are favourable to the production of ignition interference at the higher frequencies. More or less obvious, these are improved propagation conditions due to increased phase difference between direct and reflected waves at a given point, except for short distances; and the metal sections of the car and the ignition leads are more comparable in size with short wavelengths, thus acting as less effective shields and more effective radiators.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.), Ministry of Aircraft Production, and copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

AIRCRAFT AND ACCESSORIES.

TRANSLATION NUMBER AND AUTHOR.	TITLE AND REFERENCE.
1148 Molokov, V. S....	*The Civil Air Fleet of the U.S.S.R.* (Civil Aviation, U.S.S.R., Vol. 8, Aug., 1938, pp. 1-6.)
1150 Pirath, C. ...	*20 Years of Regular Air Services and Problems of Commercial Flight. I. 20 years of Regular Air Services.* (Forschungsergebnisse des Verkehrswissenschaftlichen Instituts für Luftfahrt an der Technischen Hochschule Stuttgart, No. 14, 1940, pp. 12-42.)
1151 Kaul, H. W. ...	*Statistical Observations of Service or Operational Stresses in Aeroplane Wings.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Supplement, pp. 307-313.)

ENGINES AND ACCESSORIES.

1137 Riggi, A. ...	*Variation of Aircraft Engine Power at Altitude.* (Riv. Aeron., Vol. 16, No. 1, Jan., 1940, pp. 1-32.)
1139 Benz, H. ...	*Fluid Couplings for Vehicle Propulsion with Particular Reference to the Voith Turbo Couplings.* (A.T.Z., Vol. 41, No. 9, 10/5/38, pp. 242-8. Translated by the Bristol Aeroplane Company, Limited.)
1149 Weise, A. ...	*Energy Transformation in the Radiator.* (Lilienthal Society Lectures, 1937, pp. 269-76.)
1152 Nüll, W. von der	*Centrifugal Compressors.* (Die Kreiselrad-Arbeitsmaschinen, 1937, pp. 73-84.)

MATERIALS.

1136 Fomin, N. ...	*Design of Riveted Connections.* (Trans. C.A.H.I., Moscow, No. 205, 1935.)
1138 Heyer, H. O. ...	*The D.V.L. Testing Machine for Bearing Metals under Dynamic Loads.* (L.F.F., Vol. 14, No. 1, 20/1/37, pp. 14-25.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING JANUARY, 1941, TOGETHER WITH LIST OF NEW TRANSLATIONS RENDERED AVAILABLE.

Theory and Practice of Warfare.

ITEM NO.		TITLE AND JOURNAL.
73/1	Italy ...	*Cant Z* 1007 *bis Bomber.* (Aeroplane, Vol. 59, No. 1,542, 13/12/40, p. 680.)
73/2	Germany ...	*F.W.* 187 "*Destroyer*" (*Photographs*). (Aeroplane, Vol. 59, No. 1,542, 13/12/40, p. 681.)
73/3	Great Britain	*The Slip Wing Fighter.* (N. Pemberton-Billing, Flight, Vol. 38, No. 1,669, 19/12/40, pp. 524-5.)
73/4	Great Britain	*High Explosive Bombs.* (B. Brady, Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 30-7.)
73/5	Great Britain	*Bomb Hazards Assessed.* (Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 52-3.)
73/6	Great Britain	*Midget Military Aeroplanes.* (W. O. Manning, Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 62-6.)
73/7	Great Britain	*Illusions by Camouflage.* (Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 68-69.)
73/8	Italy ...	*Italian Dive Bomber S.M.* 85. (Aeroplane, Vol. 59, No. 1,544, 27/12/40, p. 740.)
73/9	Germany ...	*New German* 5.2 *in. A.A. Gun.* (Aeroplane, Vol. 59, No. 1,544, 27/12/40, p. 742.)
73/10	Great Britain	*The Slip Wing Fighter.* (N. Pemberton-Billing, Flight, Vol. 38, No. 1,670, 26/12/40, pp. 550-2.)
73/11	Great Britain	*The Physics of Air Raids.* (*Effects of Blast; Protection of Shelters.*) (D. Bernal, Engineering, Vol. 150, No. 3,911, 27/12/40, p. 514.)
73/12	Italy ...	*Savoia Marchetti S.M.* 79 *Bomber.* (Aeroplane, Vol. 59, No. 1,543, 20/12/40, p. 704.)
73/13	Germany ...	*Me* 110 (*Photographs*). (Aeroplane, Vol. 59, No. 1,543, 20/12/40, pp. 696-705.)
73/14	U.S.A. ...	*Douglas Dive Bombers S.B.D.* (Inter. Avia., No. 734, 5/11/40, p. 7.)
73/15	Italy ...	*Italian Torpedo Carrying Aircraft S.*79. (Inter. Avia., No. 735, 12/11/40, p. 7.)
73/16	U.S.A. ...	*Boeing B-17 Flying Fortresses.* (Inter. Avia., No. 735, 12/11/40, p. 8.)
73/17	U.S.A. ...	*Twin-Engined Attack Bomber Martin* 187 (*Baltimore*). (Inter. Avia., No. 735, 12/11/40, p. 9.)
73/18	U.S.A. ...	*U.S.A. Bomb Sight.* (Inter. Avia., No. 735, 12/11/40, p. 12.)
73/19	Great Britain	*Aerial Navigation Applied to Bombing Raids on Unseen Targets.* (F. Chichester, Aeronautics, Vol. 3, No. 6, Jan., 1941, pp. 50-56.)
73/20	Great Britain	*British Military Aircraft Types Illustrated.* (Aeroplane, Vol. 59, No. 1,541, 6/12/40, pp. 632a-639 and 641-652.)

ITEM NO.		TITLE AND JOURNAL.
73/21	Great Britain	*American Views on New British Military Types.* (Aeroplane, Vol. 59, No. 1,545, 3/1/41, pp. 4-5.)
73/22	Italy ...	*Breda 88 Italian Fighter-Bomber.* (Aeroplane, Vol. 59, No. 1,545, 3/1/41, p. 14.)
73/23	Great Britain	*New British Military Aircraft and Engines.* (L. Engel, Flight, Vol. 39, No. 1,671, 2/1/41, pp. 10 and 16.)
73/24	Great Britain	*Quantity Production of Whitley Bombers.* (Flight, Vol. 39, No. 1,671, 2/1/41, pp. 13-16.)
73/25	Italy ...	*Fiat G.50 Single-Seat Fighter.* (Aeroplane, Vol. 60, No. 1,546, 10/1/41, p. 40.)
73/26	Great Britain	*Identification of Aircraft Simplified (Comparison of Hurricane and Me 109 Single-Seat Fighters).* (Flight, Vol. 39, No. 1,672, 9/1/41, p. 27.)
73/27	U.S.A. ...	*Consolidated B.24 Four-Engined Bomber.* (Flight, Vol. 39, No. 1,672, 9/1/41, p. 28.)
73/28	Great Britain	*Aircraft Carriers: Dimensions, Performance and Aircraft Capacity.* (Flight, Vol. 39, No. 1,672, 9/1/41, pp. a-e.)
		AERO- AND HYDRODYNAMICS.
73/29	Italy ...	*New Italian Wind Tunnel at the Breda Works.* (Inter. Avia., No. 734, 5/11/40, p. 6.)
73/30	Italy ...	*Experimental Results with Aerofoils Tested in the High Speed Tunnel at Guidonia.* (A. Ferri, Atti di Guidonia, No. 17, 20/9/39. N.A.C.A. Tech. Memo. No. 946, July, 1940.) (Abstract available.)
73/31	Germany ...	*A Simple Approximation Method for Obtaining the Spanwise Lift Distribution.* (O. Schrenk, Luftwissen, Vol. 7, No. 4, April, 1940, pp. 118-120. N.A.C.A. Tech. Memo. No. 948, Aug., 1940.) (Abstract available.)
73/32	U.S.S.R. ...	*On the Theory of Unsteady Planing and the Motion of a Wing with Vortex Separation.* (L. Sedov, C.A.H.I. Report No. 252, 1936. N.A.C.A. Tech. Memo. No. 942, May, 1940.) (Abstract available.)
73/33	U.S.A. ...	*Wind Tunnel Tests of an N.A.C.A. 23021 Aerofoil Equipped with a Slotted Extensible and a Plain Extensible Flap.* (T. A. Harris and R. S. Swanson, N.A.C.A. Tech. Note No. 782, Nov., 1940.) (Abstract available.)
		AIRCRAFT AND AIRSCREWS.
73/34	Great Britain	*Note on the Determination of the Drag of Retractable Undercarriages in Flight.* (J. A. C. Williams, J. Roy. Aer. Soc., Vol. 44, No. 360, Dec., 1940, pp. 862-864.)
73/35	Great Britain	*Timm P.T. 160K "Plastic" Trainer (Photograph).* (Aeroplane, Vol. 59, No. 1,542, 13/12/40, p. 684.)
73/36	Great Britain	*Air Screw Spinners.* (K. B. Gillmore, Flight, Vol. 38, No. 1,669, 19/12/40, p. 526.)
73/37	Great Britain	*The Beating Noise of Aircraft.* (T. S. Littler, Aeronautics, Vol. 3, No. 5, Dec., 1940, p. 35.)
73/38	U.S.A. ...	*Some American Blind Approach Systems.* (Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 40-41.)
73/39	Great Britain	*Flotation Altitude during Forced Landings at Sea.* (J. A. Medhurst, Flight, Vol. 38, No. 1,670, 26/12/40, p. 553.)

ITEM NO. TITLE AND JOURNAL.

73/40 Great Britain *Vibration Pattern of Propeller Blades.* (G. S. Baker, Engineering, Vol. 150, No. 3,911, 27/12/40, pp. 518-519.)

73/41 Great Britain *Feathering Airscrews.* (L. B. Greensted, Aeroplane, Vol. 59, No. 1,543, p. 711.)

73/42 Great Britain *Rotol V.P. Airscrew with Blade Setting by Electric Motor.* (Inter. Avia., No. 734, 5/11/40, pp. 4-5.)

73/43 Italy ... *New Italian Transport Plane Ca-216.* (Inter. Avia., No. 734, pp. 5-6.)

73/44 Japan ... *Japanese Flying Boat Kawasaki.* (Inter. Avia., No. 735, 12/11/40, p. 7.)

73/45 U.S.A. ... *Curtiss-Wright Substratosphere Airliner C.W.20.* (Inter. Avia., No. 735, pp. 8-9.)

73/46 Great Britain *The Prediction of Performance.* (W. Stepniewski, Airc. Eng., Vol. 12, No. 142, Dec., 1940, pp. 361-365.)

73/47 Great Britain *Prevention of Ice on Windscreen.* (N.A.C.A. Tech. Note 754. L. A. Rodert, Airc. Eng., Vol. 12, No. 142, Dec., 1940, pp. 366-369.)

73/48 U.S.A. ... *Instrument Landing in the U.S.A. with Special Reference to the Indianapolis System.* (Airc. Eng., Vol. 12, No. 142, Dec., 1940, pp. 370-77.)

73/49 U.S.A. ... *Standardisation in Aeroplane Design.* (J. T. Thompson, Airc. Eng., Vol. 12, No. 142, pp. 373-4 and 882.)

73/50 Great Britain *Vibration of Propeller Blades (Account of the Work of the N.P.L.).* (Nature, Vol. 146, No. 3,713, 28/12/40, p. 843.)

73/51 Great Britain *Plastic Wings Over the Empire (Editorial Discussing the Vidal Process).* (Plastics, Vol. 5, No. 44, Jan., 1941, pp. 1-2.)

73/52 Great Britain *Flight without Power: The Art of Gliding and Soaring (Book Review).* (L. B. Barringer, London; Sir Isaac Pitman and Sons, Ltd., 1940, 251 pp., price 17/6. Nature, Vol. 147, No. 3,715, 11/1/41, pp. 38-9.)

73/53 Great Britain *Undercarriages.* (R. Hadekel, Aeroplane, Vol. 59, No. 1,545, pp. 23-26.)

73/54 Great Britain *Bristol Blenheim—Quantity Production Methods.* (B. Foster, Airc. Prod., Vol. 3, No. 27, Jan., 1941, pp. 7-16.)

73/55 U.S.A. ... *A Flight Investigation of Exhaust Heat De-Icing.* (L. A. Rodert and A. R. Jones, N.A.C.A. Tech. Note No. 783, Nov., 1940.) (Abstract available.)

73/56 U.S.A. ... *Mechanism of Flutter. A Theoretical and Experimental Investigation of the Flutter Problem.* (T. Theodorsen and I. E. Garrick, N.A.C.A. Report No. 685, 1940.) (Abstract available.)

73/57 U.S.A. ... *Air Forces on Radial Air-Cooled Engine Cowlings as Determined from Pressure Distribution Tests.* (R. R. Higginbotham, J.S.A.E., Vol. 47, No. 3, Sept., 1940, pp. 370-96.)

ENGINES AND ACCESSORIES.

73/58 Great Britain *The Development of the Brown Boveri Axial Compressor.* (Seippet, Brown Boveri Review, May, 1940, pp. 108-113. Met. Vick. Tech. News Bull., No. 742, 20/12/40, p. 9.) (Abstract available.)

ITEM NO.		TITLE AND JOURNAL.
73/59	Great Britain	*The Application of the Two-Stroke Heavy Oil Engine to Aircraft Propulsion (with Discussion).* (W. S. Burn, Flight, Vol. 38, No. 1,670, 26/12/40, pp. a-545 and 552.)
73/60	U.S.A. ...	*Allison V-710-015 12-Cylinder Engine.* (Inter. Avia., No. 734, 5/11/40, pp. 7-8.)
73/61	U.S.A. ...	*Lycoming Flat Twelve Engine* o-1230. (Inter. Avia., No. 734, 5/11/40, p. 8.)
73/62	Great Britain	*Dimensionless Characteristics of Turbines and Pumps.* (J. Jennings, Engineer, Vol. 170, No. 4,434, 3/1/41, p. 12.)
73/63	Great Britain	*Rotary Vane Vacuum Pump.* (Engineering, Vol. 151, No. 3,912, 3/1/41, pp. 6-7.)
73/64	Great Britain	*British Aero Motors.* (Aeroplane, Vol. 59, No. 1,541, 6/12/40, pp. 653-658.)
73/65	Germany ...	*Tests of Lead-Bronze Bearings in the D.V.L. Bearing Testing Machine.* (G. Fischer, L.F.F., Vol. 16, No. 7, 20/7/39, pp. 370-383. N.A.C.A. Tech. Memo. No. 943, June, 1940.) (Abstract available.)
73/66	Italy ...	*Italian High-Speed Aeroplane Engines.* (C. F. Bona, Paper presented at the 5th Volta Congress at Rome, Sept. 30th-Oct. 6th, 1935. N.A.C.A. Tech. Memo. No. 944, June, 1940.) (Abstract available.)
73/67	Germany ...	*Experiments on Ball and Roller Bearings under Conditions of High Speed and Small Oil Supply.* (G. Getzlaff, Jahrbuch der deutschen L.F.F., Vol. 2, 1938, pp. 110-118. N.A.C.A. Tech. Memo. No. 945, July, 1940.)
73/68	Germany ...	*The Maximum Delivery Pressure of Single-Stage Radial Superchargers for Aircraft Engines.* (W. von der Nüll, Luftwissen, Vol. 7, No. 5, May, 1940, pp. 174-180. N.A.C.A. Tech. Memo. No. 949, Aug., 1940.) (Abstract available.)
73/69	U.S.S.R. ...	*Determination of Free Oscillation Frequency of Turbine Blades.* (I. K. Chernishevsky, Sov. Kotloturbo, No. 8, 1940, pp. 269-73. Met. Vick. Tech. News Bull., No. 743, 3/1/41.) (Abstract available.)
73/70	U.S.A. ...	*Problem of Valve-Stem and Valve-Head Deposits.* (A. T. Colwell, J.S.A.E., Vol. 47, No. 3, Sept., 1940, pp. 358-65.) (Abstract available.)
73/71	U.S.A. ...	*Design and Shop Problems in High Pressure Hydraulic Systems.* (H. W. Adams, J.S.A.E., Vol. 47, No. 3, Sept., 1940, pp. 367-9.)
73/72	U.S.A. ...	*Guiberson Aero Diesel.* (Flight, Vol. 39, No. 1,671, 2/1/41, p. 9.)
73/73	Great Britain	*A New Vacuum Pump (Fenton-Smith Bros.).* (Aeroplane, Vol. 60, No. 1,546, 10/1/41, pp. 54-6.)

FUELS AND LUBRICANTS.

73/74	Great Britain	*New Lubricant for Precision Instruments.* (Nature, Vol. 146, No. 3,712, 21/12/40, p. 810.)
73/75	U.S.A. ...	*Modern Fuels and Lubricants for Diesels (Review of Papers presented at November S.A.E. Meeting).* (P. M. Heldt, Autom. Ind., Vol. 83, No. 11, 1/12/40, pp. 582-587 and 616.)

ITEM NO.		TITLE AND JOURNAL.
73/76	U.S.A. ...	*Diesel Fuels for Easy Starting.* (L. A. Blane, Autom. Ind., Vol. 83, No. 11, 1/12/40, p. 616.)
73/77	Great Britain	*Town's Gas Fuel for Petrol Engines.* (Engineer, Vol. 170, No. 4,434, 3/1/41, p. 12.)
73/78	Great Britain	*Gas Filling Stations for Motor Transport.* (Engineer, Vol. 170, No. 4,434, 3/1/41, p. 12.)
73/79	U.S.A. ...	*On the Mechanism of Boundary Lubrication I. The Action of Long-Chain Polar Compounds.* (O. Beeck, J. W. Givens and A. E. Smith, Proc. Roy. Soc., Vol 177, No. 968, 31/12/40, pp. 90-102.) (Abstract available.)
73/80	U.S.A. ...	*On the Mechanism of Boundary Lubrication II. Wear Prevention by Addition Agents.* (O. Beeck, J. W. Givens and E. C. Williams, Proc. Roy. Soc., Vol. 177, No. 968, 31/12/40, pp. 103-118.) (Abstract available.)
73/81	Great Britain	*Some New Developments in the Petroleum Industry.* (W. D. Williams, Chem. and Ind., Vol. 60, No. 2, 11/1/41, pp. 22-4.)
73/82	U.S.A. ...	*Estimating Oil Viscosity at Zero Degrees.* (J.S.A.E., Vol. 47, No. 3, Sept., 1940, p. 397.)
		INSTRUMENTS.
73/83	Great Britain	*The Mark IX Sextant.* (F. Chichester, Aeroplane, Vol. 59, No. 1,542, 13/12/40, pp. 669-670.)
73/84	U.S.A. ...	*Pyrometry, especially of Molten Steel.* (Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 549.)
73/85	Great Britain	*Electrical Tachometers.* (Baker, Electrical Review, 27/12/40, pp. 179-80. Met. Vick. Tech. News Bull., No. 743, 3/1/41.)
		MATERIALS.
73/86	Great Britain	*Analysis of Rigid Jointed Framework.* (E. H. Lewitt, J. Roy. Aer. Soc., Vol. 44, No. 360, Dec., 1940, pp. 849-861.)
73/87	Great Britain	*Resistance Welding.* (Nature, Vol. 146, No. 3,711, 14/12/40, p. 784.)
73/88	Great Britain	*Application of X-Rays to the Study of Alloys.* (H. Lipson, Nature, Vol. 146, No. 3,712, 21/12/40, pp. 798-801.)
73/89	Great Britain	*Some Modern Electrical Insulating Materials.* (H. Warren, J. Inst. Elec. Engrs., Vol. 87, No. 528, Dec., 1940, pp. 588-96.)
73/90	Great Britain	*Review of Recent Papers on Magnesium Alloy Construction for Aeroplanes.* (Light Metals, Vol. 3, No. 36, Jan., 1941, pp. 3-6.)
73/91	Great Britain	*Test Bars for Light Alloy Castings.* (F. A. Allen and J. Morgan, Light Metals, Vol. 3, No. 36, Jan., 1941, pp. 17-18.)
73/92	Great Britain	*Age Hardening Magnesium Alloys.* (W. F. Chubb, Light Metals, Vol. 3, No. 36, Jan., 1941, pp. 19-20.)
73/93	Great Britain	*Compressed Impregnated Timber.* (R. M. Lloyd, Aeroplane, Vol. 59, No. 1,542, pp. 682-684.)
73/94	Great Britain	*Welding Metal to Glass.* (Aeroplane, Vol. 59, No. 1,542, 13/12/40, p. 688.)

ITEM NO.		TITLE AND JOURNAL.
73/95	Great Britain	*Specification for Wire Rope for Kite Balloons.* (Aeroplane, Vol. 59, No. 1,542, 13/12/40, p. 688.)
73/96	Great Britain	*Non-Destructive Production Tests for Steel Tubing.* (Steel, 21/10/40, pp. 38-40 and 75. Met. Vick. Tech. News Bull., No. 742, 20/12/40, p. 6.) (Abstract available.)
73/97	Great Britain	*Development in Wood Technology.* (D. Brownlie, Engineering, Vol. 150, No. 3,911, 27/12/40, pp. 502-3.)
73/98	Great Britain	*Yield Point and Proof Stress (Review of American Papers dealing with the Tension Test).* (The Metallurgist, Supplement to Engineer, 27/10/40, pp. 137-8.)
73/99	Great Britain	*The Jigging of Modern Airframes.* (Airc. Eng., Vol. 12, No. 142, pp. 375-80 and 382.)
73/100	Great Britain	*Magnesium Alloys in Aircraft.* (N. E. Woldman, Metal Industry, Vol. 57, No. 24, 13/12/40, pp. 465-8.) (Abstract available.)
73/101	Great Britain	*Application of Anodised Aluminium. A Review of Patents.* (Metal Industry, Vol. 57, No. 26, 27/12/40, pp. 502-5.)
73/102	U.S.A. ...	*Spotwelding in Aircraft Construction. Details of American Equipment and Design. (Paper to Amer. Welding Socy.)* (C. F. Marschner, Metal Industry, Vol. 57, No. 24, 13/12/40, pp. 506-9.)
73/103	Belgium ...	*Plane Braced Frames Loaded Perpendicularly to their Planes. A New Application of Cross' Method.* (J. Roy. Aer. Soc., Vol. 44, No. 359, Nov., 1940, pp. 827-43.) (Abstract available.)
73/104	Germany ...	*New Equipment for Testing the Fatigue Strength of Rivetted and Welded Joints.* (W. Müller, Special Reprint of Schweizer Archiv., No. 10, 1937. N.A.C.A. Tech. Memo. No. 947, July, 1940.) (Abstract available.)
73/105	Germany ...	*Buckling Tests with a Spar-Rib Grill.* (J. Weinhold, L.F.F., Vol. 17, No. 3, 20/3/40, pp. 76-81. N.A.C.A. Tech. Memo. No. 950, Sept., 1940.) (Abstract available.)
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73/107	U.S.A. ...	*Rating of Aircraft Quality Steels—Magnaflux Inspection.* (J. B. Johnson, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 382-3.)
73/108	U.S.A. ...	*Chromium Steels from 2-16 per cent. Chromium.* (H. D. Newall, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 384-6.)
73/109	U.S.A. ...	*Nickel Steels and Irons.* (J. W. Sands, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 387.)
73/110	U.S.A. ...	*Titanium in Iron and Steel.* (G. F. Comstock, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 387-8.)
73/111	U.S.A. ...	*Vanadium in Steel.* (J. Strauss, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 389-91.)
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73/113	U.S.A. ...	*Rubber Coatings on Metals.* (H. E. Cook, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 430-1.)

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73/114	U.S.A. ...	*Plating of Aircraft Parts.* (G. E. Stoll, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 435.)
73/115	U.S.A. ...	*Developments in Surface Finish.* (J. M. S. Hutchinson and J. M. Lessells, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 435.)
73/116	U.S.A. ...	*Stainless Steel—The Next Step for Aircraft.* (W. B. Stout, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 461-2.)
73/117	U.S.A. ...	*Metals for High Temperature Service.* (J. J. Kanter, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 463.)
73/118	U.S.A. ...	*Nickel, Inconel, Monel.* (H. E. Searle, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 466-7.)
73/119	U.S.A. ...	*Welding of Aluminium.* (G. O. Hogland, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 483.)
73/120	U.S.A. ...	*Electric Arc Welding.* (W. J. Chaffee, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 489.)
73/121	U.S.A. ...	*Resistance Welding.* (E. J. del Vecchio, Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 490.)
73/122	U.S.A. ...	*Oxy-Acetylene Welding.* (J. H. Zimmerman, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 491-2.)
73/123	U.S.A. ...	*Atomic Hydrogen Arc Welding.* (R. F. Wyer, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 493-4.)
73/124	U S.A. ...	*Aircraft Engine Forgings.* (H. J. Fischbeck, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 513-4.)
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73/126	U.S.A. ...	*Aluminium Aircraft Forgings.* (L. W. Davis, Metal Progress, Vol. 38, No. 4, Oct., 1940, pp. 515-6.)
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73/129	U.S.A. ...	*Machinery for Mechanical Testing.* (Metal Progress, Vol. 38, No. 4, Oct., 1940, p. 550.)
73/130	Great Britain	*Creep Properties of a Carbon Molybdenum Cast Steel.* (Tapsell and Prosser, Proc. Inst. Mech. Eng., Dec., 1940, pp. 91-6. Met. Vick. Tech. News Bull., No. 743, 3/1/41.)
73/131	Great Britain	*Controlled Atmosphere Heat Treating.* (Gier, Steel, 9/12/40, pp. 76-80. Met. Vick. Tech. News Bull., No. 743, 3/1/41.)
73/132	Great Britain	*Adhesives and Cements (based on Synthetic Resins).* (E. E. Halls, Plastics, Vol. 5, No. 44, Jan., 1941, pp. 5-8.)
73/133	Great Britain	*Reflections on Synthetic Rubber (Historical Development of the Industry).* (A. A. Appleby, Plastics, Vol. 5, No. 44, pp. 9-11.)
73/134	Great Britain	*Magnesium in Aircraft Construction.* (Airc. Prod., Vol. 3, No. 27, Jan., 1941, pp. 17-18.)
73/135	Great Britain	*Welding of Air Frames.* (W. S. Corns, Airc. Prod., Vol. 3, No. 27, Jan., 1941, pp. 21-25.)
73/136	Great Britain	*Taper Bore Rivets.* (Airc. Prod., Vol. 3, No. 27, Jan., 1941, p. 25.)
73/137	Great Britain	*Rivets from Light Alloy Sheet.* (Airc. Prod., Vol. 3, No. 27, Jan., 1941, p. 26.)

ITEM NO. TITLE AND JOURNAL.

73/138 Great Britain *Finishing Stainless Steel Welds.* (Aircr. Prod., Vol. 3, No. 27, Jan., 1941, pp. 32-33.)

73/139 Great Britain *Optical Flats.* (Aircr. Prod., Vol. 3, No. 27, Jan., 1941, pp. 34-5.)

73/140 U.S.A. ... *Stress Distribution in, and Equivalent Width of Flanges of, Wide, Thin-Wall Steel Beams.* (G. Winter, N.A.C.A. Tech. Note No. 784, Nov., 1940.) (Abstract available.)

73/141 Great Britain *Protective Coating on Tin Plate by Chemical Treatment.* (R. Kerr, J. Soc. Chem. Ind. (Absts. " B "), Vol. 59, No. 12, Dec., 1940, pp. 259-265.)

73/142 Great Britain *Research on Refractory Materials.* (Engineering, Vol. 151, No. 3,913, 10/1/41, pp. 34-35.)

Meteorology and Physiology.

73/143 Great Britain *The Chemical Exploration of the Stratosphere.* (F. A. Paneth, Chem. and Ind., Vol. 60, No. 1, 4/1/41, pp. 8-9.) (Abstract available.)

73/144 U.S.A. ... *Weather Analysis and Forecasting (McGraw-Hill, New York, 1940, 490 pp., price $5).* (S. Petterssen, U.S. Air Services, Vol. 25, No. 12, Dec., 1940, p. 22.)

Miscellaneous.

73/145 Great Britain *Thermodynamics and the Lowest Temperatures.* (C. G. Darwin, J. Inst. Elec. Engrs., Vol. 87, No. 528, Dec., 1940, pp. 581-587.)

73/146 Great Britain *Statistical Methods in Engineering Practice (Sampling Inspection in the Control and Standardisation of Quality).* (H. Rissik, Engineer, Vol. 170, No. 4,433, 27/12/40, pp. 404-6.)

73/147 Great Britain *Steam Generation at High Pressures.* (R. F. Davis, Engineer, Vol. 170, No. 4,433, 27/12/40, pp. 412-4.)

73/148 Germany ... *Private War Risks Insurance in Germany.* (Inter. Avia., No. 734, 5/11/40, p. 14.)

73/149 Great Britain *The Physics of Steam Generation.* (R. F. Davis, Engineering, Vol. 151, No. 3,912, 3/1/41, pp. 17-20.)

73/150 Great Britain *The Physics of Steam Generation.* (R. F. Davis, Engineering, Vol. 151, No. 3,913, 10/1/41, pp. 38-40.)

73/151 Great Britain *Factory Lighting in War Time.* (Engineer, Vol. 170, No. 4,436, 10/1/41, p. 37.)

Photography.

73/152 Great Britain *Interpretation of Aerial Photographs.* (H. J. A. Wilson, Aeronautics, Vol. 3, No. 5, Dec., 1940, pp. 26-31.)

73/153 Great Britain *R.A.F. Night Photography.* (Flight, Vol. 170, No. 4,433, 27/12/40, p. 415.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
Directorates of Scientific Research and Technical Development, Air Ministry.
(Prepared by R.T.P.)

No. 88. MARCH, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example that published by the Aeronautical Research Committee) is already known to these Staffs.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revenue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.

J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes.
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A. or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Verceffentlichungen aus dem Gebtete der Nachrichtentecgnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwesen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

A History of External Ballistics. (F. Klemm, W.T.M., Vol. 45, No. 1, Jan., 1941, pp. 1-8.) (88/1 Germany.)

The author deals with the main points of development in flight path theory from the middle ages up to modern times. Galileo (1638) was the first to establish the parabolic nature of the path in the absence of air resistance. The effect of the latter could only be taken into account after the requisite mathematical tool (diffferential calculus) had become available (Newton and Leibniz). Bernoulli and Euler (1745) were the first to apply the new method to practical problems. A British gunnery officer, B. Robins in his "New Principles of Gunnery" (1742) pointed out the importance of projectile spin in ensuring stability. This rotation, however, also causes certain deviations in the path, the calculation of which presented considerable difficulties at first. We now know that the observed deviation is the resultant of three effects: The so-called cushion effect of Poisson (1839), the Magnus or Rotor effect (1852) and the gyroscopic effect (1852). Individually, these effects may work in opposite directions and

the final result will depend on their relative magnitude. As its name implies, the cushion effect is due to the presence of a layer of compressed air in the immediate neighbourhood of the projectile. If the latter is cylindrical and slightly inclined to the path tangent, a clockwise spin (viewed from the rear) will tend to produce a right hand deviation (rolling action). This effect is generally small. The Magnus or rotor effect, on the other hand, will produce a much more pronounced left hand deviation if acting by itself under otherwise similar circumstances.

It will be noted that both these effects only become operative if for some reason the nose of the rotating bullet rises above the tangent to the flight path. As soon as this happens, however, the third effect mentioned above becomes operative. The projectile acts as a gyroscope and under the assumed conditions (clockwise spin viewed from the rear) it will precess towards the right, the axis describing the surface of a cone. If this precession is slow enough, the right hand deviation observed in practice is accounted for, since calculation shows that its magnitude is considerably greater than the left hand deviation due to the Magnus effect. (The cushion effect, which also leads to a right hand deviation, is generally very small.) More recently it has, however, been shown that the precession is relatively rapid (in the case of the German infantry bullet the cone is described in 0.11 seconds) and the simple explanation of the right hand deviation offered above thus breaks down. Closer examination has shown that the precessional cone is of the cycloidal type and remains predominantly on the right hand side of the vertical plane passing through the tangent to the path. In spite of the periodic nature of the oscillations, therefore, a right hand deflection predominates which increases with distance.

Other landmarks in external ballistics are provided by the well known air resistance formula of Siacci (1896) which covers experimental results for bullet velocities between 150 and 900 m./sec. and which led to the satisfactory integration of low angle trajectories.

An alternative graphical method has more recently been developed by Cranz and Rothe which can also be applied to high angle trajectories.

Fundamental Principles of Sound Locators. (O. Born, Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, pp. 251-255.) (88/2 Switzerland.)

Aircraft noises are due to the engine, propeller and complete structure. Exhaust noises are generally of low frequency, *e.g.*, a 12-cylinder four-stroke running at 2,100 r.p.m. has an exhaust frequency of 210/sec. Other engine noises are due to the supercharger which emits frequencies of the order of 4,000/sec. The fundamental propeller frequency is, on the other hand, generally less than 100/sec. The remaining structural noises are of various frequencies and generally of no great importance.

The summation of all these various sounds produces the characteristic aircraft noise (including possible beats in a case of twin engines) which must be located by the detector.

Generally speaking, the ear is most sensitive to low frequency sounds and therefore long range detection will depend primarily on exhaust and propeller noise. Sense of direction depends on differences in time of reception by the two ears. It appears that intervals as small as 1/34,000 seconds can be detected. In the sound locator full use is made of this by artificially increasing the base line from 30 cm. (average head distance) to 300 cm. Under these conditions a directional accuracy of the order of $\pm 2^\circ$ should be obtainable.

At the same time it is important that the reception should show no deterioration of quality, as with trained personnel it is possible to determine the type of aircraft from its characteristic note, and thus estimate its probable speed. A knowledge of the speed of the target is of importance, since the locator, even should the sound waves travel in straight lines, cannot give the instantaneous

direction of the aircraft but must lag behind it by an angle approximately given by V/a in circular measure (V = aircraft speed, a = velocity of sound). This correction can be incorporated automatically in a fairly simple manner. Much more difficult is a proper allowance for wind and temperature gradients, especially if discontinuities exist. The usual procedure is to neglect such effects entirely and to rely on a searchlight for the final spotting.

In conclusion, the author gives some indication of the method of training adopted by the Swiss army for their sound locating personnel. It appears that only 7 per cent. of the candidates possess initially the necessary acuteness of hearing to warrant further training. It is interesting to note that this talent is not limited to any special class and that men normally employed in factories where they are subject to a continual background of noise are just as likely to possess it as, for example, musicians and scientists.

Turbulence and Energy Dissipation. (A. A. Kalinske, Trans. A.S.M.E., Vol. 63, No. 1, Jan., 1941, pp. 41-8.) (88/3 U.S.A.)

The origin and dissipation of turbulence energy is studied with a view to understanding the mechanics of the energy losses produced by various flow-disturbing devices, such as expansions, bends, valves, etc. The important parameters characterising turbulence are the root-mean-square values of the fluctuating velocity components, the length factor proportional to the size of the small eddies responsible for the dissipation of energy and the length factor proportional to the average size of the eddies. The effect of variation of these parameters on the energy losses occurring in turbulent flow are discussed and also the change in these parameters in the decaying turbulence beyond turbulence-producing devices is indicated. Data are presented showing the variation in kinetic energy of mean flow and the turbulence energy in a 15° conical divergence. Visual studies of the start of turbulence at rounded entrances to smooth conduits seem to indicate that there is regular vortex formation at the boundary and the dispersion of these vortices into the main fluid stream gradually establishes normal turbulent flow.

Some Aspects of Non-Stationary Aerofoil Theory and its Practical Application. (W. R. Sears, J. Aeron. Sci., Vol. 8, No. 3, Jan., 1941, pp. 104-8.) (88/4 U.S.A.)

This paper consists of three notes on the theory of two-dimensional thin aerofoils in non-uniform motion:—

1. In the first note expressions for the lift and moment of an oscillating aerofoil are collected from an earlier paper and are presented in convenient forms for practical application.

2. In the second note the lift and moment are calculated for a rigid aerofoil passing through a vertical gust pattern having a sinusoidal distribution of intensity. The lift is determined as a function of the reduced frequency (which in this case is proportional to the ratio of the aerofoil chord and the wave length of the gust pattern) and is presented in the form of a vector diagram. It is shown that the lift acts at the quarter chord point of the aerofoil at all time.

3. In the third note the results of 1 and 2 are applied to the calculation of the amplitude of torsional oscillation of a fan blade operating in the wake of a set of pre-rotation vanes. In a numerical example the amplitude is found to be small even when the vanes are spaced so that the exciting frequency coincides with the natural frequency of the fan blade.

The Wind Tunnel with Open Working Section. (N. Simmons, Phil. Mag., Vol. 31, No. 205, Feb., 1941, pp. 89-102.) (88/5 Great Britain.)

The solution of the problem of a weak vortex in a two-dimensional jet issuing from a channel has previously been taken as a basis in calculating corrections

for an aerofoil placed in a wind tunnel stream (N. Simmons, Quart. J. Math., Oxford, Dec., 1939). However, the true physical condition of a tunnel with open working section can be more closely approached by taking as a starting point a stream which, after having left the channel and met the vortex, passes into a collecting channel of similar form. The purpose of the present paper is to discover whether the introduction of such a collector leads to any modification of the formulæ given in the paper cited, and, if so, to determine them. The hydrodynamical problem is dealt with first, the assumption that the vortex is weak, which is valid in the practical application, being introduced at the outset in order to render the analysis tractable. The aerodynamical sequel is considered and the results discussed.

On Turbulent Liquid Motion Outside a Circular Boundary. (M. Ray, Phil. Mag., Vol. 31, No. 205, Feb., 1941, pp. 144-55.) (88/6 Great Britain.)

In a previous paper (Phil. Mag., Vol. 28, 1939, p. 231) the problem of turbulent motion of an otherwise uniform stream in the neighbourhood of a circular boundary has been discussed from the point of view of " vorticity transport " theory of Taylor. The starting point was the Taylor-Goldstein equations, which were transformed into forms suitable for treatment of motion near a circular boundary. A solution was obtained in that paper by successive approximations, and it was also pointed out that the approximation must necessarily be restricted to regions very near the boundary. Since then it has been possible to reconstruct an almost correct solution numerically even of the complicated exact differential equation describing the motion. In the previous paper only an approximate form of the complicated equation was taken. The initial values required to start the numerical integration have been supplied by the approximation solutions very close to the boundary obtained in the previous paper. The construction of the velocity field and the stream lines near the circular boundary shows some important features of the motion. The motion in the neighbourhood of the boundary is retrograde, which gradually changes into direct motion at a distance from the circular wall equal to about a third of the radius of the circular boundary. On this circle the velocity is entirely radial. The velocity perpendicular to the wall near any part possesses a maximum which is attained within a distance not exceeding about a quarter of the radius of the circular boundary. The present investigation does not extend to the region where the wake is formed. The nature of the stream lines is shown in Fig. 4.

Section 2 is a recapitulation of the first part of the previous paper giving all the necessary equations of motion.

Wind Tunnel Correction for a Circular Open Jet Tunnel with a Reflexion Plate. (B. Davison and L. Rosenhead, Proc. Roy. Soc., Vol. 177, No. 970, 24/2/41, pp. 366-82.) (88/7 Great Britain.)

It is advantageous from many points of view to make test models as large as possible. One method of doing this is to measure the characteristics of half the model in existing wind tunnels. One half of the aerofoil is mounted horizontally on a vertical reflexion plate and the plate is placed in a suitable position in an open jet which, in the undisturbed state, is of circular section. The contour of the jet is distorted, especially with models of large semi-span, but this distortion is neglected in the analysis. The correcting factor associated with " uniform " distribution of lift is worked out exactly and that associated with " elliptic " distribution approximately. The effect of the induced downwash on the distribution of lift is ignored. The results are given in suitable tables and figures.

Throughout the working range of normal experiments the correcting factor is of the same order of magnitude as that obtaining when a full model is tested in a jet of circular section.

Cascade Theory and the Design of Fan Straighteners. (A. R. Collar, R. and M. No. 1,885, 22/1/40.) (88/8 Great Britain.)

It is usual to provide a set of straighteners for the fan of a wind tunnel, and often for ventilating and other fans. The function of straighteners is to remove the rotation from the fan slipstream. It is of particular importance to do this in a return flow wind tunnel, since otherwise there may be a rotation in the stream at the working section. Moreover, if the slipstream rotation is not removed, stalling of parts of the corner cascades is likely to occur, with a consequent loss of power and irregularity of velocity distribution.

Straighteners commonly consist of a bank of fixed radial vanes placed behind the fan; the dimensions and setting of the vanes are determined from the fan characteristics. In the present report the possibiiity is examined of designing a set of straighteners which will render the flow axial, irrespective of the sense or, within reasonable limits, of the magnitude of the slipstream rotation. An examination is made of the experimental and theoretical evidence available for the design of such straighteners. It is concluded that, provided stalling does not occur, a ring of straighteners of symmetrical aerofoil section, set radially with their chords parallel to the axis of the fan, and having a gap-chord ratio of approximately unity (so that the local chord is proportional to the radius), will remove rotation from the slipstream of a fan to a degree sufficient for most practical purposes.

The Combustion-Gas Turbine. (J. T. Rettaliata, Trans. A.S.M.E., Vol. 63, No. 2, Feb., 1941, pp. 115-23.) (88/9 U.S.A.)

At the present time the principal commercial application of the gas-turbine axial-compressor unit in the United States has been in oil refineries. Air discharged from the compressor is used in a process and the resulting high temperature gases are expanded in the turbine, producing power, the excess of which is supplied to a generator. In this arrangement, no combustion chamber is required as the process itself acts in this capacity.

Many gas-turbine axial-compressor units operate as superchargers in the Velox boiler, developed by Brown-Boveri, where the boiler exhaust gases drive the turbine.

A 4,000 kw. unit has been installed in an emergency stand-by power station in the city of Neuchatel, Switzerland. Its simplicity and independence of water facilities ideally adapt the gas turbine to this class of service. Recently published tests, conducted by Stodola indicate a coupling thermal efficiency, based on lower heating value of fuel, of 18.04 per cent. for this unit when operating on a non-regenerative cycle with a turbine inlet temperature of 1,000°F. This is the first unit built for the primary purpose of producing power.

A 2,200 h.p. gas turbine locomotive, with electrical transmission, is being built by Brown-Boveri for Swiss Federal Railways.

Numerous other natural and favourable applications of the gas-turbine axial-compressor unit will develop from time to time and probably include marine propulsion, blast furnace plants, wind tunnels, special power plants, and other special applications.

Technical Progress in Aviation. (J. C. Hunsaker, Mech. Eng., Vol. 63, No. 2, February, 1941, pp. 95-97.) (88/10 U.S.A.)

According to the author, the U.S. have the potential ability "to make obsolete all fighter aeroplanes in the world to-day, including our own." Two new types of air-cooled radial engines developing over 2,000 h.p. are already developed and in production and the N.A.C.A. have devised means of ducting and cowling these engines so that their drag is as low as that of the best liquid-cooled engine installations in use at the present time. Moreover, new wing

sections have been devised which maintain laminar boundary layer flow over a greater area of wing surface and thus have smaller drag than standard types.

The interesting situation has arisen that a very large production programme for 1,200 h.p. fighter aeroplanes, based on European liquid-cooled engines, has been launched at the very time these new factors have arisen.

In the words of the author: "*When* we should take advantage of this recent technical progress is a delicate question involving a balance between strategic and tactical considerations. It is the old dilemma of quantity *now* versus quality *later* and can be decided wisely only when we know whether it really is later than we think."

Recent Progress in Aeronautics. (Progress Report of the A.S.M.E. Aeronautics Division.) (Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 101-104 and 116.) (88/11 U.S.A.)

Some of the main conclusions are given below:—

Aerodynamics.—(1) The laminar flow aerofoil mentioned in the last year's report is still under development. One reason is the necessity of obtaining extreme surface smoothness before the advantages of this section can be realised. Also, other difficulties must be overcome. It is hoped that a practical solution will soon be found.

(2) Correlation between flight and wind tunnel tests requires further research so as to allow for more accurate performance predictions.

(3) Propeller cuffs designed primarily to improve cooling have led to increase in propeller efficiency.

(4) Flying characteristics (manœuvrability) are at last becoming amenable to quantitative treatment and improvements are anticipated. The quest for high speed has led to the introduction of wings with a higher taper ratio in order to reduce weight, and this in its turn has brought about difficulties due to tip stalling. Means of avoiding this without increasing drag are still being sought. The same applies to measures for stopping a fully developed spin.

Accessories.—(1) Injection carburettors have established themselves, with possible use of safety fuels in the near future.

(2) Remote reading instruments utilising either A.C. or D.C. are coming into greater use. Dual indication on one dial saves space and weight.

(3) An automatic radio magnetic compass has been perfected which enables the pilot to fly towards or away from a radio station regardless of cross winds.

Power Plants.—(1) Both the Wright Aeronautical Corporation and Pratt and Whitneys have produced 18-cylinder twin row air-cooled radial engines of 2,000 h.p. and over. The Wright engine has a capacity of 3,350 cu. in. and develops 2,200 h.p. The Pratt and Whitney produces 2,000 h.p. for a capacity of 2,800 cu. in.

It is interesting to note that the double row radials have practically the same specific weight as the earlier single row radials of approximately half the output (1.1 lb./take-off h.p.).)

(2) The liquid-cooled engines have the advantage over the radial that a more slender fuselage can be employed which should reduce drag. The Allison 12-cylinder liquid-cooled engine is now going into large scale production, which has necessitated an enormous expansion both of personnel and facilities. It is pointed out that relatively little service experience with this engine is available up to now and this necessitates "continual proof testing of parts and completed engines to provide the knowledge and experience that would in turn be correlated with actual normal and accelerated aeroplane flight tests."

(3) The total engine production (all classes) in the U.S.A. for Sept., 1940, was of the order of 2,400 units. It is expected that this monthly output will be doubled in a year's time.

(4) Variable reduction gears for propellers, if sufficiently simple, light and reliable, seem to offer outstanding advantages for high speed high altitude flight.

(5) Extension shaft drives are receiving considerable attention.

Since at the present moment most technical information is treated as confidential and not published, the above survey is necessarily incomplete. Thus very little can be said about possible progress in jet propulsion which is receiving attention in various quarters.

Aeroplane Performance Testing at Altitude. (A. C. Reed, J. Aeron. Sci., Vol. 8, No. 4, Feb., 1941, pp. 135-50.) (88/12 U.S.A.)

The method of obtaining, presenting, and reducing flight test performance data at altitude covered by this paper gives a means of checking the accuracy of each point against all of the other points. The data obtained at any given altitude are not considered as data separate and by themselves. They are considered in relation to all of the data obtained at all of the altitudes tested. By this means the inaccuracies of any individual point are reduced to a minimum. By checking the theory against the flight test and flight test against the theory, it is possible to obtain a rational shape to the curves that are faired to the data. Having obtained a reduction of the data that is consistent with theory, it is possible to interpolate very accurately for any condition of weight, power, altitude, and temperature and extrapolate with good accuracy and to within reasonable limits.

The methods presented in this paper have been developed only for the simple gear-driven supercharger. For some time development work has been progressing on exhaust-driven turbo superchargers. The factors that affect the power output of such an installation are more numerous and more involved than for the gear-driven supercharger. Some excellent testing has been done on the ground. Other testing has been done and is being done in the air. The evaluation of all of the factors involved has not yet been determined and will be the basis of extensive research in the future.

The constant trend toward increasing speeds has already brought aeroplane performance into the outer fringes of the effects of compressibility. The entire development of the methods presented in this paper has essentially neglected the effect of compressibility of the atmosphere, except in so far as minor corrections may account therefore. The complete answer to the question of how this effect will be handled in the interpretation and reduction of aeroplane performance does not appear immediately.

Shear Centre of a Multi-Cell Metal Wing. (H. W. Sibert, J. Aeron. Sci., Vol. 8, No. 4, Feb., 1941, pp. 162-6.) (88/13 U.S.A.)

The general principles for obtaining the shear centre of a multi-cell metal wing by means of the least work of shear have been given by Hatcher (J. Aeron. Sci., Vol. 4, No. 6, April, 1937, pp. 233-238). Due to the complexity of the analysis only single-cell beams, such as leading edge wing beams, have been treated so far. The purpose of this paper is to extend the methods developed to metal wings containing two or more cells. Since the effect of taper on shear centre is apparently small for modern metal wings, the analysis will be limited to a wing of uniform cross-section.

Simple formulas based on the least work of shear are given for the co-ordinates of the shear centre and the shear force per unit length of arc of a multi-cell wing beam. The terms involved in these formulas are ordinary summations or can be evaluated by Simpson's rule according as concentrated areas or skin effective in bending is concerned. A numerical example is worked out for the case of a two-cell wing beam with skin on the tension side effective in bending.

Constructional Principles of the Escher-Wyss Variable Pitch Propeller. (A. von der Mühll, Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, pp. 258-260.) (88/15 Switzerland.)

The propeller mechanism is operated by oil pressure and is normally of the constant speed type, the pressure being controlled by a centrifugal governor, which is set for the required speed by the pilot. Several novel features are incorporated in the design. Thus the feathering or breaking positions of the blades are brought about by the pilot putting a second oil pump into operation. This not only prevents these blade settings being assumed accidentally (since the first pump is insufficient to produce the necessary rotation), but also ensures that these positions are reached quickly when wanted, a point of great practical importance.

Under steady flight conditions, the blades are locked mechanically, thus preventing oil leakage. The same locking takes place automatically, should the oil pressure fail accidentally.

The design of the hub is symmetrical and lends itself to the installation of a cannon. The blades can be unscrewed without dismantling the hub. Alternately, the piston control mechanism for the blades can be withdrawn from the hub without dismantling the blades. Servicing is thus facilitated and it is stated that the propeller has been adopted by the Swiss Air Force.

No weights are given.

The C.U.E. Co-operative Universal Engine for Aviation Single-Cylinder Research. (A. W. Pope, J.S.A.E., Vol. 48, No. 1, Jan., 1941, Transactions, pp. 33-40.) (88/16 U.S.A.)

The standardised single-cylinder aviation research engine originally designed in 1937 proved suitable for investigation of spark plugs but was not adequate for fuel and oil tests. Since then a volunteer group, organised by the S.A.E., has studied and co-ordinated the requirements of such an engine and from five complete designs a combination has been developed which appears to be completely satisfactory. The single-cylinder crankcase design was dimensioned to take the Wright Cyclone air-cooled cylinder $6\frac{1}{8} \times 6\frac{3}{8}$ in. bore and stroke, the largest in use at the time. The C.U.E. engine is described in detail, including the following features:—The balancing system; main roller bearings; smooth-walled crank chamber; lubrication; crankcase construction; temperature control; crankcase seal; accessory drives; crankshaft; connecting rod; spark indicator; flywheel; reverse rotation; dynamometer coupling; and fuel injection system.

Fifteen C.U.E. engines have already been built and 15 more are under construction.

"Averaging" Ignition Lag Meter for Compression Ignition Engines (Digest). (A. E. Traver and W. S. Mount, Autom. Ind., Vol. 84, No. 3, 1/2/41, pp. 122-123.) (88/17 U.S.A.)

The meter is essentially an electronic switch which is turned "on" by the voltage impulse from the first closure of the injection contact points, and is turned "off" by the first closure of the combustion pressure contact points. It can be applied to any Diesel engine where the injector can be fitted with some sort of mechanical pick-up or contactor and where there is an outlet in the combustion chamber for the pressure contactor.

The current flowing through the circuit during the "on" period of approximately 13° of crank angle rotation is stored in a large condenser which discharges continuously throughout the whole cycle through a micro-ammeter. Most cycle to cycle variations are thus damped out and only changes in ignition lag, due to changes in fuel quality, are recorded. A wiring diagram is given.

Comparison of Automatic Types of Exhaust Gas Analysers (Digest). (J. L. Dilworth, Autom. Ind., Vol. 84, No. 3, 1/2/41, pp. 123-124.) (88/18 U.S.A.)

Four commercial type analysers were attached to the exhaust manifold of a single-cylinder variable compression engine and simultaneous readings taken whilst both air and fuel supply were measured independently over an extended range of operation. Two of the instruments were of the thermal conductivity type, whilst the others worked on the hot wire (catalytic) and relative density principle respectively. Comparison of true and indicated air fuel ratios showed fair agreement over the mixture strength range 10/1 to 14/1. Further weakening of the mixture scarcely affected the readings of the analysers which continued to indicate ratios of the order of 13 or 14/1, whilst the true mixture was as weak as 17/1.

Quite apart from this serious defect, readings are far from consistent on the rich side and even under most favourable conditions variations of the order of $\pm 1/2$ air fuel ratio must be expected over the range 10/1 to 14/1. The instruments working either on the hot wire (catalytic) or thermal conductivity principle are lighter and more compact than those of the relative density type.

Propulsive Effects of Radiator and Exhaust Ducting. (M. Rauscher and W. H. Phillips, J. Aeron. Sci., Vol. 8, No. 4, Feb., 1941, pp. 167-74.) (88/19 U.S.A.)

It is shown how the thrust and the thermal efficiency of a ducted radiator vary with the design of the duct, the amount of radiator heating and the aeroplane speed. The type of duct commonly used for drag reduction is found to serve well for thrust recovery. Nevertheless, the thermal efficiency of the arrangement is so low that the thrust obtainable is unlikely to offset more than about one-third of the drag of the radiator and duct.

A study is made of the thrust given by a jet of fluid released in a duct. Conditions are found to exist under which the thrust of the ducted jet is greater than that of the jet unducted. If the jet consists of cool fluid, the thrust augmentation is secured by a venturi-shaped duct. With a hot jet, an expanding-contracting duct is required, as for a propulsive radiator. The analysis suggests that the potential benefits of exhaust ducting are of the same order as those of radiator ducting, but presumes steady flow conditions and applies therefore only to exhaust streams fed by numerous cylinders. Such collected streams are generally much slower than the free blasts from cylinders with individual stacks. This means that exhaust collection reduces the net impulse $\int F dt$ on the discharged gases, and hence the work $\int F ds = \int F r_1 dt = r_1 \int F dt$ done by the net exhaust reaction F on the engine moving at the velocity of r_1. If the noise and glare of unmuffled exhaust flashes could be tolerated, or could be blanketed from view and hearing, it would thus be advantageous to use individual stacks, preferably shaped into expanding nozzles.

The Significance of Diesel Exhaust Gas Analysis. (J. C. Holtz and M. A. Elliott, Trans. A.S.M.E., Vol. 63, No. 2, Feb., 1941, pp. 97-105.) (88/20 U.S.A.)

Data on exhaust gas composition, obtained in a study of the hazards that might attend the use of Diesel engines underground, are discussed in relation to combustion in the Diesel engine. Two engines were tested throughout a wide range of fuel-air ratios, and the results indicated that combustion was essentially complete in the normal operating range, although even under these conditions low but significant concentrations of carbon monoxide, aldehydes, and free carbon were present in the exhaust gases. The concentration of carbon monoxide, determined by precise analytical methods, was a minimum at a fuel-air ratio of approximately 0.03 lb. per lb. and was affected by engine design and to a slight extent by factors that varied with speed. The co-existence of aldehydes

and free carbon indicated that direct oxidation and destructive combustion of the fuel were occurring simultaneously. The calculation of combustion efficiency from data on the products of incomplete combustion is illustrated.

Lateral Stiffness and Vibration in Engine Structures. (R. Pyles, Trans. A.S.M.E., Vol. 63, No. 2, Feb., 1941, pp. 107-14.) (88/21 U.S.A.)

The forces tending to produce horizontal vibration in engine frames may be obtained from the bearing-load diagrams. For an eight-cylinder nine-bearing engine, the dominant forces occur at the centre main bearing and bearings Nos. 3 and 7. The first major horizontal critical speed is the eighth order, which will come into resonance when the engine speed is one eighth the natural horizontal frequency of frame.

In view of the difficulty of predicting the horizontal frequency of the complicated frame structure, a simplified empirical method of comparing stiffness of frames is given.

The Influence of the 24-Cylinder (2,000 h.p.) Engine on the Development of the Fighter Bomber. (C. Rougeron, Inter. Avia., No. 751,20/2/41, pp. 1-3.) (88/22 France.)

In any aircraft, not only the weight but also the question of disposable space plays an important rôle. In the case of a fighter, both bombs and extra fuel could be carried if only space could be found. This difficulty has existed for years and is due to the fact that whilst engine power has increased very considerably, frontal area has not. Since the smallest possible fuselage is built round the engine, there is besides the cockpit no new disposable space. Similarly, any new wing space which might become available has so far been taken up by machine guns and the retractable undercarriage.

These matters are likely to change, now the 24-cylinder 2,000 h.p. H or X engine is becoming available. During the period 1930-1940 engine weight was practically constant, the increase in power being obtained mainly by boost and speed.

The new 24-cylinder engines will, however, weigh at least twice as much as the old 12-cylinder arrangement, and with the increase in armament necessitated by the higher speed, it is likely that the new fighters will weigh round about 10,000 lb. against a former weight of 5,000 lb. The wing area will have to be approximately doubled and the fuselage volume will be more than doubled in order to house the larger power plant.

Extra space now becomes available for either fuel or bombs and the long range fighter or really high speed bomber becomes a possibility.

An Instrument for Continuous Measurement of Piston Temperatures. (A. F. Underwood and A. A. Catlin, J.S.A.E., Vol. 48, No. 1, Jan., 1941, Transactions, pp. 20-7.) (88/23 U.S.A.)

The thermocouple method for measurement of piston temperatures involves problems relating to the measuring instrument or instruments required, installation of the thermocouples in the piston and the electrical connections connecting the two. In the present work the regular galvanometer supplied with the commercial potentiometer selected for use was replaced by a standard light beam galvanometer, whose sensitivity could be controlled by means of a variable resistance connected across its terminals. The contact device described enables continuous measurement of one temperature or intermittent measurement of several temperatures. Test data obtained with this instrument and discussed in the paper include temperature gradients of both aluminium and cast iron pistons, the effect of load variation on piston temperature and the effect of spark advance on piston temperature. A production engine fitted with the final design of the instrument has been run for 25,000 miles at 60 m.p.h. on a dynamometer

without attention or adjustments. A test car installation has shown that measurements can be made continuously on the road.

Quantity Production of Gyro Instruments. (P. R. Bassett, Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 98-100 and 124.) (88/24 U.S.A.)

Irrespective of the rate of increase in demand for a particular instrument, its production history usually exhibits three phases: (1) Lots of 10; (2) lots of 100; (3) lots of 1,000. The first is the engineer's phase, every instrument being checked for proper functioning. In the next stage (lots of 100) the foreman checks for uniformity of product, but experts are still necessary for individual performance of each instrument. Production proper is not reached till lots of 1,000 are reached. No single person checks every instrument, but control of materials and workmanship are the main concern. The paper deals particularly with the methods adopted by the Sperry Company for the large scale production of gyro horizons and directional gyros. Already in 1937, orders for certain parts were placed with sub-contractors working in the vicinity, experts being also supplied by the parent firm to assist in fitting the work to the machine, helping to train the men, when necessary modifying the original jigs and fixtures to suit the new conditions. Gradually the number of sub-contractors was extended, unsuitable firms being discarded at an early stage. After two years, 25,000 machine hours per month had become available, distributed over 21 sub-contractors. Sub-contracted machine hours had risen to 140,000 by April, 1940 (32 firms) and the figure of 200,000 was aimed at by the end of that year. At the same time the output of the parent firm expanded so that the ratio of the machine hours worked bore a reasonably constant ratio to the sub-contracted hours. Certain critical parts of the gyro instruments are never subcontracted. Also all the assembly work, calibration and testing is done by the parent firm. It is claimed that by their method of sub-contracting, the Sperry Instrument Company were able to increase rate of production eight-fold and satisfy all emergency demands of the future.

The "Plug" Method for Obtaining the Compressive Elastic Properties of Thin-Walled Sections. (H. W. Barlow, H. S. Stillwell and Ho-Shen Lu, J. Aeron. Sciences, Vol. 8, No. 3, Jan., 1941, pp. 109-114.) (88/25 U.S.A.)

A new method is proposed for use in determining the compressive elastic properties of thin-walled sections. The method consists essentially in supporting the section with a cement plug which restrains the flat sides of the specimens from early secondary failure. The method of preparing specimens is simple and inexpensive. Results are given for a large number of compressive stress-strain tests, plotted, using a modification of Osgood's non-dimensional system of co-ordinates. The method is believed to be preferable to the "pack" or "coil" method in that it permits the direct testing of the fabricated section and thus gives the true compressive property of the section itself. If the test specimen is properly prepared, as described, the possibility of the plug causing appreciable shearing forces between the walls and the plug is so small as to be negligible, and any possible compression of the plug when the specimen has been shortened under load is eliminated.

The plug method is applicable to both closed and open sections.

Spot Welding Development at the Arado Works. (E. Reichel, Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 538-48; Translated in Airc. Eng., Vol. 13, No. 144, Feb., 1941, pp. 49-54.) (88/26 Germany.)

Tests made with the A.E.G. electric welding machine, based on the principle of grid control and providing exact regulation of the current, have proved that welding can be substituted for riveting for joining parts of hydronalium sheet. An important increase in fatigue strength of the welded parts can be obtained

by subsequent annealing at 330°C. for 60 mins. The fatigue strength then exceeds that of similar riveted parts. A large stressed component, in the form of the fuselage of a single-seat fighter, has been welded and tested in flight. Welding can also be used conveniently for aluminium components and for elektron so long as the sheet thickness does not exceed 0.8 mm. For thicker elektron sheet it proved advisable to anneal, shortly before welding, at 300°C. for 5-10 minutes. Duralumin material has presented greatest difficulties in electrical spot and seam welding, and further research is required. By comparison with riveting, production may be increased two or three times by seam welding, while obtaining a considerable reduction in production costs.

Fire-Extinguishing Effectiveness of Chemicals in Water Solution. (H. D. Tyner, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 60-5.) (88/27 U.S.A.)

Results are presented of over eight hundred tests on wood cribs to measure the fire extinction effectiveness of water solutions of thirty-three chemical compounds in various concentrations, and the results of similar tests with water alone.

The study indicates the advantages that may be obtained by adding chemicals to the water used. Results of several other investigators are reviewed.

The experimental results obtained at the Forest Products Laboratory, using water solutions of chemicals to extinguish standard test fires indicate the following :—

1. The superiority of a given concentration of a given chemical compound in water, over water alone, varies with both the rate of application of the liquid and the wind velocity.

2. As extinguisher solution application rates approach the minimum rate at which extinction can be accomplished with water, the amount of water required increases greatly, whereas the amount of a 10 per cent. monoammonium phosphate solution required remains approximately constant.

3. The superiority of a 10 per cent. monoammonium phosphate solution over water is greater with moderate wind velocities (up to 15 miles per hour) than at zero wind velocity.

4. Several of the most effective agents in concentrations of about 2 per cent. possess a large part of the extinction effectiveness attained with much higher concentrations.

5. Chemicals vary in their capacity to knock down flames quickly and in prevention of glowing and rekindling. Potassium acetate, potassium bicarbonate, and potassium carbonate have pronounced flame-extinguishing capacity. Phosphoric acid, di- and monoammonium phosphates, and boric acid have pronounced glow-extinguishing and total extinguishing capacity.

6. A survey of the results and theories of other investigators indicates that the fire-retarding action of chemicals is related to both physical and chemical properties. For the effective agents studied, possession of one or both of the following capabilities seems to be important: (*a*) Reduction of the volume of combustible gas formed (by increasing the proportion of charcoal formed); (*b*) formation of a fused inactive surface-protective layer upon the combustible surface. Cooling the seat of the fire, the smothering action of liberated, inert gas, and catalytic action may be contributing factors, but their importance seems very limited.

Identification of Light Scrap. (Engineer, Vol. 171, No. 4,442, 28/2/41, p. 145.) (88/28 Great Britain.)

Three solutions are recommended as sufficient to identify the light metal alloys when in scrap form: No. 1, 30 per cent. nitric acid solution in water; No. 2, 20 per cent. caustic soda solution; and No. 3, 5 per cent. hydrochloric acid

solution in water. Solution No. 1 produces a positive reaction only with magnesium base alloys of the elektron type. A drop of this solution placed on a perfectly clean surface of such alloy will produce a pronounced white colouration after a few minutes. This test is quite suitable for the identification of magnesium base alloy scrap. The alloys aluminium-silicon and aluminium-magnesium-silicon are indicated by a greyish-brown colouration with No. 2 solution. Pure aluminium is indicated when no etching reaction is obtained with Nos. 1 and 3 solutions. If a drop of No. 2 solution produces a black stain, the alloys containing copper (aluminium-copper and aluminium-copper-zinc) are indicated. If on wiping off the remaining caustic soda solution a drop of No. 3 solution removes the black stain, the scrap tested belongs to the group aluminium-copper-zinc.

Statistical Control of Materials and Manufactured Products. (J. Geschelin, Autom. Ind., Vol. 84, No. 3, 1/2/41, pp. 128-129 and 139-140.) (88/32 U.S.A.)

Statistical inspection is essentially a sampling control applied to materials or manufactured articles which are themselves produced under controlled conditions. Once standard conditions have been established, any variation outside some determined limits indicates that some change has taken place which in a large majority of cases can be readily traced.

When introducing the method, it may be safer to restrict it to materials or products which have relatively wide limits of acceptance. As experience is gained, sampling control can eventually be applied to processes in which a 100 per cent. inspection was the traditional procedure. As an example, the surface finish of crankpins and journals is given. Originally this required inspection of every crank with the profilometer, together with a continuous record of the finishing process so that the latter could be checked and corrected. Eventually the method of finishing would be under control and instead of inspecting every sample, the examination of small batches at hourly or daily intervals will suffice.

The aim throughout is to produce a better article at a less cost and speed up production.

A useful bibliography of 12 recent publications on the subject of statistical control is given.

Iron-Base Hard-Facing Metals. (V. E. Alden, Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 149-51.) (88/33 U.S.A.)

An outstanding development of the last four years in the field of hard facing has been the development of iron-base alloys, containing chiefly the relatively less costly constituents iron, chromium, nickel, molybdenum, and carbon. The wearing qualities of these alloys in the presence of temperatures up to at least 1,350°F. are equal or superior to those of the cobalt-chromium-tungsten alloys, made up of more expensive constituents. This family of iron base alloys goes under the name of "Coast Metals."

Excellent control can be exercised over these iron base alloys to give all sorts of interesting properties. Various coefficients of expansion are obtainable by slight modifications of the basic analysis and thus hard surfacing of cylindrical sections of all types of steels and irons can be guaranteed free from checks or cracks.

One respect in which the experience with these iron-base hard-facing alloys differs from the experience outlined for the cobalt-chromium-tungsten alloys is that a majority of the applications have been made by arc welding. There are, however, a limited number of applications, such as the hard facing of the cutting edges of shears and dies where Coast Metals can usually be best applied by gas.

Preparation of Automobile Bodies for Painting. (V. M. Darsey, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 2, Feb., 1941, pp. 222-4.) (88/34 U.S.A.)

Successful application of paint to steel parts depends upon thorough cleaning and suitable chemical pre-treatment. Methods used for preparing automobile bodies for painting are:—Phosphating, phosphoric acid cleaning and solvent cleaning. Of these the phosphating (Bonderizing) process is now most widely employed and consists in spraying the Bonderite solution by means of a completely mechanised equipment on to the bodies as they are carried by conveyor through an enclosed tunnel which combines cleaning, phosphating, rinsing and drying in one continuous operation. A solution commonly used for rust proofing is prepared by dissolving zinc or manganese dihydrogen phosphate in water.

Frequent testing of finished bodies by an accelerated humidity test serves as a check on all chemical pre-treatments prior to painting. Salt spray tests also prove that increased protection is obtained from paint applied over phosphated surfaces compared with that afforded by the same paint finish over solvent cleaned metal without phosphating.

The Column Strength of Closed, Thin-Walled Sections of 18-8 *Stainless Steel.* (H. W. Barlow, J. Aeron. Sci., Vol. 8, No. 4, Feb., 1941, pp. 151-61.) (88/35 U.S.A.)

Thin-walled members having closed cross-sectional shapes are used as columns in aircraft construction. The purpose of this investigation was to determine and evaluate the factors influencing the behaviour of such columns fabricated from 18-8 corrosion-resistant steel. Approximately 300 specimens comprising two different cross-sectional shapes in nominal thicknesses of 0.006 in., 0.008 in., 0.010 in., 0.012 in., 0.014 in., were tested as columns under flat-end and under pin-end conditions.

The fact that the physical properties of the material are subject to change with cold working makes it necessary to determine the basic strength characteristics of the material after all processing has been completed.

The compressive elastic properties of the completed sections were determined by the use of the " Plug " method. This method is fully described in a previous article by the author (J. Aeron. Sci., Vol. 8, No. 3, Jan., 1941, pp. 109-114) and consists essentially in supporting the section with a cement plug which restrains the flat sides from early secondary failure.

The column tests were analysed on the basis of the compressive elastic properties of the material. For the sections investigated it was established that in the equation for primary failure by translation, the tangent modulus in compression represents the effective modulus.

The coefficient of end-fixity for flat-end column tests was found to be 4.0.

It was established that the critical unit stress for secondary failure is directly proportional to R and is inversely proportional to the square of the flat-pitch ratio. R is defined as a section constant for any given shape. The value of R does not vary with the thickness of the material and may be determined for each section by compression tests of a few short specimens.

Experience with Metals at High Temperatures for Power Plants. (A. E. White and C. L. Clark, Trans. A.S.M.E., Vol. 63, No. 2, Feb., 1941, pp. 137-41.) (88/36 U.S.A.)

From wide experience with various metals and applications of different types, in high pressure, high temperature power plant service, the authors have selected piping and bolting materials for detailed discussion. In this field, carbon-molybdenum steel is receiving the greatest amount of attention, and so the properties, control of grain size, heat-treating practice, creep rates, and kindred matters for this material are dealt with in the paper. Based on two specifications for bolting material, issued by the American Society for Testing Materials, the

authors discuss the selection of properties, heat-treatment practice, and causes of failure in this type of material. The conclusion is reached that in so far as suitable alloys for pipes and bolts for high temperature are concerned, the art is yet in its developmental stage.

Recent Fog Investigations. (S. Petterssen, J. Aeron. Sciences, Vol. 8, No. 3, Jan., 1941, pp. 91-102.) (88/37 U.S.A.)

Fogs may be classified according to the identity of the process constituting the principal cause of their formation. A classification based on this principle is given in the following table:—

Fog Producing Processes.	Fog Dissipating Processes.
1. Evaporation from:—	1. Sublimation or condensation on:—
1. Rain which is warmer than the air (rain area fog, or frontal fog).	1. Snow with air temperature below 0°C. (excepting ice crystal fogs).
2. Water surface which is warmer than the air (steam fog).	2. Snow with air temperature above 0°C. (melting snow).
2. Cooling due to:—	2. Heating due to:—
3. Adiabatic upslope motion (upslope fog).	3. Adiabatic downslope motion.
4. Flux of air across the isobars toward lower pressure (isobaric fog; effect negligible).	4. Flux of air across the isobars toward higher pressure (effect negligible).
5. Falling pressure (isallobaric fog; unimportant).	5. Rising pressure (unimportant).
6. Radiation from the underlying surface (radiation fog).	6. Radiation absorbed by the fog or by the underlying surface.
7. Advection of warmer air over a colder surface (advection fog).	7. Advection of colder air over a warmer surface.
3. Mixing:—	3. Mixing:—
8. Horizontal mixing (unimportant by itself and strongly counteracted by vertical mixing).	8. Vertical mixing (important in dissipating of fogs and producing stratus).

The main remaining problem associated with fog investigation is that of fog forecasting. Experience has shown that formation of fog depends on many local factors, such as local sources of pollution and water, obstacles influencing air currents, local temperature effects and the local properties of the ground. It is therefore desirable that studies of local fog conditions should be organised for all the principal airports and adequately co-ordinated with theoretical fog research.

Detection of Super-cooled Fog Droplets. (R. L. Ives, J. Aeron. Sciences, Vol. 8, No. 3, Jan., 1941, pp. 120-2.) (88/38 U.S.A.)

Super-cooled fog droplets may be detected in many instances by means of a modified polariscope used in conjunction with a source of sonic disturbances. From various observations made it is concluded that any violent mechanical disturbance in a fog containing super-cooled droplets will cause them to "flash" into ice, and that an ice crystal passing through a polarised beam will cause a rotation of that beam, giving rise to the chromatic effects observed with the equipment described. It appears possible that a combination of a polariscope and a noise-maker can be used to detect the presence of super-cooled droplets with a high degree of consistency and that such a device could also be used to warn of incipient wing-icing conditions. When visual observation methods are

used the mechanism is light in weight and mounted on an aircraft need not appreciably increase air drag. A photo-electric cell can be substituted for the eye and the device be made to operate a suitable alarm system.

The Distribution of Electricity in Thunderclouds (II). (G. Simpson and G. D. Robinson, Proc. Roy. Soc., Vol. 177, No. 970, 24/2/41, pp. 281-329.) (88/39 Great Britain.)

The investigation of the distribution of electricity in thunderclouds described by Simpson and Scrase in 1937 has been continued at Kew Observatory. Alti-electrographs, which record the sign of the potential gradient, are sent up on small free balloons. Additional observations made during eight thunderstorms in the years 1937, 1938 and 1939, are discussed and the conclusions reached by Simpson and Scrase are confirmed. Each thundercloud has positive electricity in the upper half of the cloud, negative electricity in the lower half, and in most storms, if not in all, there is a concentrated positive charge below the main negative charge. The generation of the positive and negative charges in the main body of the cloud is ascribed to the impact of ice crystals and that of the positive electricity in the base of the cloud to the breaking of rain drops in an ascending current of air.

Latent Energy and Dissociation in Flame Gases. (W. T. David, A. S. Leah and B. Pugh, Phil. Mag., Vol. 31, No. 205, Feb., 1941, pp. 156-68.) (88/40 Great Britain.)

The gases remaining after flame has spread through an inflammable gaseous mixture are not just hot normal gases. The view has been put forward that they contain a considerable latent energy which, in the absence of surface, persists for a long time and which varies in amount with the initial conditions of the mixture before combustion. The latent energy probably resides in a proportion of the tri-atomic molecules formed during combustion as an excess of intra-molecular energy which cannot be handed on to the translational degrees of freedom. The experimental evidence, collected over a period of years, is briefly reviewed in Part I of this paper—attention being confined to mixtures of carbon monoxide and air, since the authors' experiments have for the most part been made with these mixtures.

In Part II experiments are described which show that there is a much larger dissociation in flame gases than in normal gases of the same composition under similar conditions of temperature and pressure. This would appear to result from the excess of intra-molecular energy in the tri-atomic molecules, and, indeed, the experiments indicate that the extent of the abnormal dissociation varies with the latent energy.

The New Specific Heats of Air and Certain Combustion Gases (Addenda and Discussion). (R. C. H. Heck, Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 126-135.) (88/41 U.S.A.)

According to the classical kinetic theory, the body of a gas at any temperature contains molecules at different energy levels, the number of such levels approaching infinity. With the advent of the quantum theory it became possible to reduce these energy levels to a definite number. Moreover, the proportional number of molecules at any particular energy level can be determined from spectroscopic data. Making use of Plank's so-called " sum of state " theorem, it is then possible to calculate the variation of specific heats with temperature. This represents a great advance, since direct calorimetric measurements of specific heat are difficult and liable to considerable sources of error, especially at high temperatures. For this reason specific heat values obtained by the new method are designated " new specific heats " and extensive tables covering the more common gases were given by the author in a previous paper, published in

the January, 1940, issue of "Mechanical Engineering." The present paper gives some extensions, but its main interest lies in the discussion.

It appears that although the theoretical basis of the new method dates back to 1907 when Einstein published his equations of the heat of oscillation of harmonic oscillators, reliable numerical calculations were first carried out by Hicks and Mitchell in 1926. During the last five years the new method has received considerable attention. The theoretical treatment of most diatomic gases appears to be completely satisfactory, and satisfactory checks have been carried out at room and ordinary temperatures by alternative methods.

The treatment of the simpler polyatomic molecules, including even some of the simpler hydrocarbons is less complete, but adequate. Thus the calculated values for CO_2 are in good agreement with those deduced from recent sound velocity measurements up to 1,000°C. The water molecule presents difficulties since the spectra are complicated and corrections have to be applied for rotational distortion of the molecule at high temperatures. Here again, however, satisfactory agreement with experimental equilibrium constants gives indirect evidence of the reliability of the new method. Speaking generally, the specific heat values deduced by the new method are 5-10 per cent. higher than those previously accepted. (Abstractor's Note: Report of Empire Motor Fuels Committee, I.A.E., 1924.)

A study of the basis of the method indicates the possibility of some additional quantum states existing which are as yet undiscovered. This may lead to a further (small) increase in the final true values. It appears quite certain that no future discovery can lead to a decrease in the values given by the author.

In conclusion, it must be emphasised that the "new" specific heat values as tabulated apply only to the ideal state (infinitely dilute).

Conversion to higher pressures requires a knowledge of the equation of state of the substance. The correction in the specific heat due to "imperfections" is, however, generally small for the common gases with the exception of H_2O. In the case of air it amounts to about 1 per cent. at temperatures above 0°C. and pressures below 150 lb. per sq. in.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.), Ministry of Aircraft Production, and copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

AIRCRAFT AND ACCESSORIES.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND REFERENCE.
1153-4	Kimmerle, O. ...	*Twenty Years of Regular Air Services and Problems of Commercial Flight II. The Influence of Altitude and Direction of Flight on Safety and Efficiency in Commercial Aviation* (*Parts* 1 *and* 2). (Forschungsergebnisse des Verkehrswissenschaftlichen Instituts für Luftfahrt an der Technischen Hochschule Stuttgart, No. 14, 1940, pp. 43-87 and 87-111.)
1155	Vladimirov, A. N.	*Standards of Transverse Stability for Flying Boats.* (Aeron. Eng., U.S.S.R., Vol. 14, No. 4-5, April-May, 1940, pp. 62-70.)

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1150-61	Portier, H. ...	*The Riveting of Thin Metal Plates in Aircraft Construction* (*Parts* 1-10). (Pub. Sci. et Tech., B.S.T., No. 87, 1939, pp. 1-50, 51-85, 86-99, 100-139, 140-164 and 165-192.)
1163	Englisch, C. ...	*The Modulus of Elasticity of Piston Ring Materials. Determination and Significance.* (A.T.Z., Vol. 40, No. 17, 10/9/37, pp. 431-4.) (Translated by the Bristol Aeroplane Co., Ltd.)
1166	Müller, J.	*The Cause of Welding Cracks in Steels Used for Aircraft Construction.* (L.F.F., Vol. 17, No. 4, 20/4/40, pp. 97-105.)

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1162	Kuhlenkamp, A. ...	*Co-ordinate Systems in Anti-Aircraft Defence.* (Z.V.D.I., Vol. 84, No. 51, 21/12/40, pp. 1005-9.)
1164	Wedemeyer, E. A.	*Some Cases of Unusual Tyre Wear.* (A.T.Z., Vol. 42, No. 6, 25/3/39, pp. 157-61.)
1165	Poggi, L.	*The Velocity Field in a Two-Dimensional Flow of Compressible Fluid. Part II. Case of Profiles Obtained by Conformal Transformation from the Circle and, in particular, of Joukowski Profiles.* (L'Aerotecnica, Vol. 14, No. 5, May, 1934, pp. 532-50.)
1167	Berg, H. H. ...	*A Method of Measuring Blade Temperatures in Gas Turbines.* (Z.V.D.I., Vol. 84, No. 10, 11/5/40, pp. 329-30.)

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Theory and Practice of Warfare.

ITEM NO.		TITLE AND JOURNAL.
72/1	Great Britain	*Hawker Hurricane Single-Seat Fighter.* (Flight, Vol. 38, No. 1,662, 31/10/40, pp. 369/h and 371-373.)
72/2	Great Britain	*Vickers-Armstrong Wellington Bomber.* (Aeroplane, Vol. 59, No. 1,537, 18/11/40, pp. 510-521 and 523-524.)
72/3	U.S.A. ...	*Aeroplanes from the U.S.A. Some Notes on Design.* (Aeroplane, Vol. 59, No. 1,537, 8/11/40, pp. 527-528.)
72/4	Germany ...	*Ju. 88 Twin Engine Dive Bomber (Photograph).* (Aeroplane, Vol. 59, No. 1,536, 1/11/40, p. 481.)
72/5	Great Britain	*Some Notes on the Art of Baling Out.* (G. Johns, Aeroplane, Vol. 59, No. 1,536, 1/11/40, pp. 493-494.)
72/6	Great Britain	*Air Raid Damage and Munitions Production.* (Engineering, Vol. 150, No. 3,905, 15/11/40, p. 392.)
72/7	Germany ...	*Air Force Targets in Germany XI. Politz Hydrogenation Works near Stettin.* (Engineer, Vol. 170, No. 4,427, 15/11/40, pp. 312-3.)
72/8	U.S.A. ...	*Boeing B.17 and Douglas Big Bombers.* (Engineer, Vol. 170, No. 4,427, 15/11/40, p. 320.)
72/9	Germany ...	*Heinkel He 111K Night Bomber.* (Flight, Vol. 38, No. 1,665, 21/10/40, pp. a-c.)
72/10	Germany ...	*F.W. 187 "Destroyer" (Photographs).* (Aeroplane, Vol. 59, No. 1,538, 15/11/40, p. 543.)
72/11	Great Britain	*The Cazeau Effect.* (W. T. D. Allan, Aeroplane, Vol. 59, No. 1,538, 15/11/40, p. 549.)
72/12	Great Britain	*Glider Trains for Troop Transport.* (O. L. L. Fitzwilliams, Aeroplane, Vol. 59, No. 1,538, 15/11/40, pp. 552-555.)
72/13	Great Britain	*Aircraft Identification by Sound.* (C. Campbell, Flight, Vol. 38, No. 1,664, 14/11/40, p. 412.)
72/14	Germany ...	*Notes on the Armament of Enemy Aircraft (Armour Plate, Guns and Bombs).* (Flight, Vol. 38, No. 1,664, 14/11/40, pp. a-f.)
72/15	Italy ...	*Fiat B.R. 20 Two-Motor Bomber.* (Aeroplane, Vol. 59, No. 1,539, 22/11/40, p. 570.)
72/16	U.S.A. ...	*Treated Plywood Bomb-Bay Door (G. L. Martin Co.).* (American Aviation, Vol. 4, No. 10, 15/10/40, p. 3.)
72/17	Great Britain	*Progress of Camouflage.* (Nature, Vol. 146, No. 3,702, 12/10/40, p. 482.)
72/18	Great Britain	*A New Apparatus for the Detection of Mustard Gas.* (F. C. Hymas, Chem. and Ind., Vol. 59, No. 29, 20/7/40, pp. 779-780.)
72/19	Great Britain	*Camouflage in Modern Warfare.* (Nature, Vol. 146, No. 3,706, 9/11/40, pp. 597-8.)
72/20	Great Britain	*Douglas B.19 Giant Bomber.* (Aire. Prod., Vol. 11, No. 12, Dec., 1940, pp. 395-398.)

ITEM NO.		TITLE AND JOURNAL.
72/21	Germany ...	*Air Force Targets in Germany. XIII. Duisburg, Ruhrort Harbour.* (Engineer, Vol. 170, No. 4,429, 29/11/40, pp. 342-4.)
72/22	U.S.A. ...	*Air Power for Defence, Strategic Requirements of Aircraft in all Services.* (J. L. H. Peck, Sci. Amer., Vol. 163, No. 6, Dec., 1940, pp. 311-4.)
72/23	U.S.A. ...	*Curtiss Wright Dive Bomber XSB2C-1.* Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 314.)
72/24	U.S.A. ...	*Puncture-Proof Inner Tubes for Combat Vehicles.* (Sci. Am., Vol. 163, No. 5, Nov., 1940, pp. 255-6.)
72/25	Switzerland...	*Some General Considerations on the Possible Errors of A.A. Fire.* (H. Brandli, Flugwehr und-Technik, Vol. 2, No. 1, Jan., 1940, pp. 9-12.) (Abstract available.)
72/26	Germany ...	*Ju 88 Bomb Racks.* (Inter. Avia., No. 732, 21/10/40, p. 7.)
72/27	Germany ...	*Arado 96 B Fighter.* (Inter. Avia., No. 732, 21/10/40, p. 8.)
72/28	U.S.A. ...	*Martin Twin-Engine Patrol Bomber, Type XPBM.* (Inter. Avia., No. 730, 4/10/40, p. 7.)
72/29	Germany ...	*Ju 88 Twin-Engined Bomber.* (Inter. Avia., No. 729, 25/9/40, pp. 2-3.)
72/30	U.S.A. ...	*Republic Dive Bomber.* (Inter. Avia., No. 729, 25/9/40, p. 4.)
72/31	U.S.A. ...	*Douglas B.19 Four-Engined Heavy Bomber.* (Inter. Avia., Nos. 726-7, 10/9/40, pp. 10-11.)
72/32	U.S.A. ...	*Lockheed P-38 Twin-Engined Interceptor.* (Inter. Avia., Nos. 726-7, 10/9/40, pp. 11-12.)
72/33	Great Britain	*Short "Stirling" Heavy Bomber.* (Inter. Avia., Nos. 724-5, 3/9/40, pp. 8-9.)
72/34	U.S.A. ...	*Northrop N.3-PB Patrol Bomber.* Inter. Avia., Nos. 724-5, 3/9/40, p. 13.)
72/35	U.S.A. ...	*Vought Sikorsky XF4U-1 Navy Fighter.* (Inter. Avia., Nos. 724-5, 3/9/40, p. 13.)
72/36	Italy ...	*A.R.P. in Italy.* (Inter. Avia., Nos. 724-5, 3/9/40, p. 17.)
72/37	Great Britain	*High Altitude Bombers.* (N. Pemberton-Billing, Vol. 38, No. 1,668, 12/12/40, pp. 502-4.)
72/38	Great Britain	*Ventilation of Air Raid Shelters.* (J. S. Weiner, Nature, Vol. 146, No. 3,710, 7/12/40, pp. 733-737.)
72/39	Great Britain	*Night Bombing: An Imperative Research.* (Engineer, Vol. 170, No. 4,431, 13/12/40, pp. 378-9.)
72/40	Great Britain	*Reinforced Concrete Air Raid Shelters.* (Engineer, Vol. 170, No. 4,431, 13/12/40, p. 382.)
72/41	U.S.A. ...	*American Four-Engined Bombers—Consolidated B.24 and Boeing B-17B.* (Aeroplane, Vol. 59, No. 1,540, 29/11/40, p. 591.)
72/42	Italy ...	*Fiat CR. 42 Single-Seat Fighter.* (Aeroplane, Vol. 59, No. 1,540, 29/11/40, p. 598.)
72/43	Great Britain	*Fairey "Fulmar" Two-Seat Fleet Fighter.* (Aeroplane, Vol. 59, No. 1,540, 29/11/40, pp. 608-9.)
72/44	Germany ...	*Ju 88 Dive Bombers (Details of Armaments, Wing Deicing, Automatic "Pull-out," Anti-flutter Devices, etc.).* (Flight, Vol. 38, No. 1,667, 5/12/40, pp. b-f.)
72/45	Great Britain	*A Survey of Aircraft Orders Placed in the United States.* (L. Engel, Vol. 38, No. 1,667, 5/12/40, pp. 472-4.)

ITEM NO.		TITLE AND JOURNAL.
72/46	Germany ...	*Ju 88 Twin-Engined Bomber.* (Inter. Avia., No. 728, 19/9/40, p. 3.)
72/47	Italy ...	*The Italian Air Force.* (Inter. Avia., No. 733, 28/10/40, p. 1-4.)
72/48	Great Britain	*Air Force Targets in Germany: Cologne and its Environments.* (Engineer, Vol. 170, No. 4,432, 20/12/40, pp. 391-3.)

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72/49	Great Britain	*Model Experiments in the Wave Tank on Beach Formation of Waves.* (R. A. Bagnold, J. Inst. Civ. Engs., Vol. 15, No. 1, Nov., 1940, pp. 27-52.)
72/50	U.S.A. ...	*Thickness of a Liquid Film adhering to a Surface Slowly Withdrawn from the Liquid.* (F. C. Morey, Bur. Stan. J. Res., Vol. 25, No. 3, Sept., 1940, pp. 385-93.) (Abstract available.)
72/51	U.S.A. ...	*Curved Flow in Conduits of Constant Cross Section.* (C. N. Nordell, Oil and Gas Journal, Vol. 39, No. 5, 1940, pp. 5, 50, 53, 55.) (Chem. Absts., Vol. 34, No. 19, 10/10/40, p. 6,491.)
72/52	Germany ...	*Flow of Viscous Oils Through Pipes.* O. Wirth, Oel und Kohle, Vol. 36, pp. 58-60.) (Chem. Absts., Vol. 34, No. 19, 10/10/40, p. 6,491.)
72/53	Great Britain	*Calculation of Terminal Speeds (Maximum Speed Falling Freely Through Viscous Fluid).* (Engineering, Vol. 150, No. 3,908, 5/12/40, pp. 441-444.)
72/55	Switzerland...	*The Effect of Compressibility in Air Flow.* (J. Ackeret, Flugwehr und-Technik, Vol. 2, No. 1, Jan., 1940, pp. 18-20.) (Abstract available.)
72/56	U.S.A. ...	*Private Wind Tunnels in the U.S.A.* (Inter. Avia., Nos. 726-7, 10/9/40, p. 12.)
72/57	Japan ...	*On the Subsonic Flow of a Compressible Fluid Past an Elliptic Cylinder.* (I. Imai and T. Aihara, Aer. Res. Inst., Tokyo, Vol. 15, No. 194, Aug., 1940.) (Abstract available.)
72/63	Great Britain	*Generalisation of Cunningham's Extension of Stoke's Law for the Force on a Sphere.* (G. Young, Math Biophysics Bull., Vol. 2, Sept., 1940, pp. 105-8.) (Sci. Absts., A, Vol. 43, No. 515, 25/11/40, p. 731.)
72/64	Great Britain	*Forces on Two Parallel Infinitely Long Plane Plates Placed in a Uniform Flow.* (Y. Nomura, Tohoku Univ. Sci. Reports, Vol. 19, June, 1940, pp. 22-35.) (Sci. Absts., A, Vol. 43, No. 515, 25/11/40, p. 731.)
72/65	Japan ...	*Flow of a Compressible Liquid Past a Sphere.* (K. Tamada, Proc. Phys. Math. Soc., Japan, Vol. 22, July, 1940, pp. 519-525.) (Sci. Absts., A, Vol. 43, No. 515, 25/11/40, p. 732.)
72/66	Japan ...	*Non-Permanent Movement of Viscous Fluids in Tubes of Very Small Diameter.* (K. Kitagawa, Proc. Phys. Math. Soc., Japan, Vol. 22, June, 1940, pp. 442-7.) (Sci. Absts., A, Vol. 43, No. 515, 15/11/40, p. 732.)
72/67	Great Britain	*Flow of Suspensions Through Narrow Tubes.* (F. J. Dix and G. W. S. Blair, J. Applied Physics, Vol. 11, Sept., 1940, pp. 574-81.)

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ITEM NO.		TITLE AND JOURNAL.
72/68	Great Britain	*Douglas DC-6 Civil Transport.* (Flight, Vol. 38, No. 1,662, 31/10/40, p. 381.)
72/69	U.S.A. ...	*Pitcairn P.A.-36 Autogiro.* (Aeroplane, Vol. 59, No. 1,536, 1/11/40, pp. 491-492.)
72/70	Great Britain	*Airscrew Spinners.* (F. G. Marshall and P. Burton, Flight, Vol. 38, No. 1,665, 21/11/40, pp. e-f.)
72/71	Great Britain	*Rotol Airscrew De-Icing Equipment.* (Flight, Vol. 38, No. 1,665, 21/11/40, p. f.)
72/72	Great Britain	*Comparison of Methods of Assisted Take-off.* (N. Pemberton-Billing, Flight, Vol. 38, No. 1,665, 21/11/40, pp. 429-432.)
72/73	Great Britain	*Hydraulic Servo Mechanisms.* (L. Pomeroy, Jr., Aeroplane, Vol. 59, No. 1,539, 22/11/40, pp. 577-580.)
72/74	Great Britain	*The "Owlet" Tricycle Trainer.* (Flight, Vol. 38, No. 1,666, 28/11/40, pp. a-g.)
72/75	U.S.A. ...	*Protecting Gasoline Tanks, Principles and Practice in Development of Bullet-Proof Tanks for Aircraft.* (A. Klemin, Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 322.)
72/76	U.S.A. ...	*Hydraulic Method for Strength Testing of Aircraft Parts.* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, pp. 322-3.)
72/81	U.S.A. ...	*Blind Landing of Aircraft (International Telephone Co. System).* (Sci. Am., Vol. 163, No. 5, Nov. 1940, p. 260.)
72/82	U.S.A. ...	*Pitcairn Autogiro P.A.-36.* Inter. Avia., Nos. 724-5, 3/9/40, pp. 12-13.)
72/83	Great Britain	*Review of British Aircraft.* (Flight, Vol. 38, No. 1,668, 12/12/40, pp. 498-499.)
72/84	Great Britain	*Runways and Assisted Take-off.* (Flight, Vol. 38, No. 1,668, 12/12/40, p. 500.)
72/85	U.S.S.R. ...	*Russian Giant Airliner L-760.* (Flight, Vol. 38, No. 1,668, 12/12/40, p. 512.)
72/86	U.S.A. ...	*Production of Aircraft Stampings.* (H. Chase, Metal Industry, Vol. 57, No. 23, 6/12/40, pp. 446-448.)
72/87	U.S.A. ...	*Douglas DC-6 Transport.* (Inter. Avia., No. 730, 4/10/40, pp. 4-6.)
72/88	Great Britain	*General Aircraft "Owlet" (Trainer for Night Flying).* (Aeroplane, Vol. 59, No. 1,540, 29/11/40, pp. 603-6 and 613.)
72/89	Great Britain	*Rotol Four-Bladed Airscrew.* (Flight, Vol. 38, No. 1,667, 5/12/40, p. 471.)
72/90	U.S.A. ...	*Plastics Trainer.* (Inter. Avia., No. 720, 25/9/40, p. 6.)
72/91	Great Britain	*Airscrew Spinners—II. The Development of Spoked, Cooling and Bullet Proof Types.* (F. G. Marshall and P. Burton, Flight, Vol. 38, No. 1,667, 5/12/40, pp. 467-8.)
72/92	Germany ...	*Universal Compass Checking Bench.* (Inter. Avia., No. 728, 19/9/40, pp. 3-4.) (Abstract available.)
72/93	U.S.A. ...	*Windshield Wipers.* (Inter. Avia., No. 733, 28/10/40, p. 8.) (Abstract available.)

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72/94 Germany ... *Diving Brakes on Ju 87.* (Inter. Avia., No. 731, 12/10/40, p. 9.) (Abstract available.)

72/95 Germany ... *Locking of Control Surfaces for Testing Aeroplanes.* (From Fuftfahrtforschung, No. 8, 1940.) (Inter. Avia., No. 731, 12/10/40, p. 10.)

72/96 Great Britain *Tyre Wear on Runways (B. Pt., No. 516, 738).* (Inter. Avia., No. 731, 12/10/40, p. 11.) (Abstract available.)

72/97 Japan ... *Measurement of the Period of Natural Vibration of an Airscrew Blade.* (J. Obata and Y. Yosida, Aer. Res. Inst., Tokyo, Vol. 15, No. 191, July, 1940.) (Abstract available.)

72/106 U.S.A. ... *Plastic Trim Tabs for Aircraft—Developed by Glenn L. Martin Co.* ((Autom. Ind., Vol. 85, No. 8, 15/10/40, pp. 434-5.)

72/107 U.S.A. ... *Synthetic Rubber Flexible Nozzle for Gasoline Hose (Able to Discharge Static Electricity).* (Autom. Ind., Vol. 83, No. 8, 15/10/40, p. 436.)

72/108 U.S.A. ... *Shock Absorbers, Testing and Measuring the Resistance of the Hydraulic Type.* (P. Douglas, Autom. Eng., Vol. 30, No. 405, December, 1940, pp. 411-2.)

72/109 Great Britain *Vibration Patterns of Propeller Blades.* (G. S. Baker, Engineering, Vol. 150, No. 3,910, 20/12/40, pp. 484-486.) (Abstract available.)

ENGINES AND ACCESSORIES.

72/110 Germany ... *Mercedes-Benz DB-601 A Aero Motor.* (Aeroplane, Vol. 59, No. 1,536, 1/11/40, pp. 490-491.)

72/111 Great Britain *The Development of the Kaplan Turbine.* (J. R. Finniecome, Engineering, Vol. 150, No. 3,905, 15/11/40, pp. 381-383.)

72/112 U.S.A. ... *Polonium Alloy for Spark-Plug Electrodes.* (R. D. Evans, J. Applied Phys., Vol. 11, 1940, pp. 561-2.) (Chem. Absts., Vol. 34, No. 19, 10/10/40, p. 6,531.)

72/113 U.S.A. ... *Current Investigation at the I.A.E. Laboratories (Mobile Gas Producer, Aeration of Oil, Gear Testing, Bearing Temperatures, Crankshaft Fatigue).* (Autom. Eng., Vol. 30, No. 403 (Extra Number), 14/11/40, pp. 333-7.)

72/114 Great Britain *Specific Speeds of Pumps and Turbines.* (J. Jennings, Engineering, Vol. 150, No. 3,908, 5/12/40, p. 454.)

72/115 Great Britain *Steam Turbine Efficiency and the Reynolds Number.* (Engineer, Vol. 170, No. 4,430, 6/12/40, pp. 363-4.)

72/116 Great Britain *Dimensionless Characteristics of Turbines and Pumps.* (H. Addison, Engineer, Vol. 170, No. 4,430, 6/12/40, p. 365.)

72/117 U.S.A. ... *Design of High-Speed Two-Stroke Engines.* (S. Treves, Autom. Ind., Vol. 83, No. 7, 1/10/40, pp. 483-5.)

72/118 U.S.A. ... *Performance of Modern Aircraft Diesels (with Discussion).* (P. H. Wilkinson, J.S.A.E., Vol. 47, No. 5, 1940, pp. 474-81.) (Abstract available.)

72/119 U.S.A. .... *Comparison of 1940 and 1941 Car Engines (Cylinders and Valves, Piston Rings, Crankshaft and Ventilation, Lubrication, Cooling Systems, Fuel System).* (T. A. Bissel, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 447-452.)

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72/122	U.S.A. ...	*Steam Turbine Blading (with Discussion).* (R. C. Allen, Trans. A.S.M.E., Vol. 62, No. 8, Nov., 1940, pp. 689-710.) (Abstract available.)
72/123	U.S.A. ...	*Water Pump Employing Helicoidal Rotor in Rubber Casing.* (Sci. Am., Vol. 163, No. 5, Nov., 1940, p. 256.)
72/124	U.S.A. ...	*Pratt and Whitney R-2,800 Engine (Double Wasp).* (Inter. Avia., No. 729, 25/9/40, pp. 3-4.)
72/125	Great Britain	*British Aero Engines.* (Flight, Vol. 38, No. 1,668, 12/12/40, pp. 506-9.)
72/126	U.S.A. ...	*Aircraft Diesels; Pitman Publishing Co., 1940 (Review).* P. H. Wilkinson, American Aviation, Vol. 4, No. 12, 15/11/40, p. 3.)
72/127	Italy ...	*Italian Experiments on Jet Propulsion.* (Inter. Avia., No. 733, 28/10/40, p. 6.) (Abstract available.)
72/132	U.S.A. ...	*Zerex Anti-Freeze Liquid (Ethylene Glycol Base, made by E. I. du Pont de Nemours).* (Autom. Ind., Vol. 83, No. 8, 15/10/40, p. 436.)
72/133	U.S.A. ...	*Fuel Injection. A Summary of Tests made with Spark-Ignition Engines (from paper to S.A.E.).* (O. W. Schey, Autom. Eng., Vol. 30, No. 405, Dec., 1940, p. 384.)
72/134	U.S.A. ...	*Diesel Engines. Experiments showing the Possibilities of Oxygen for Power Boosting (paper to A.S.M.E.).* (P. H. Schweitzer, Autom. Ind., Vol. 30, No. 405, Dec., 1940, pp. 395-7.)
72/135	Great Britain	*Some Fallacies Concerning the Petrol Engine.* (W. T. David, Engineer, Vol. 170, No. 4,432, 20/12/40, pp. 388-9.)

FUELS AND LUBRICANTS.

72/136	Great Britain	*Recent Developments in the Production of High-Speed Diesel Fuels.* (M. E. Kelly, Fuel, Vol. 19, No. 10, Nov., 1940, p. 219.)
72/137	U.S.A. ...	*Factors Involved in Lead Susceptibility of Gasolines.* (A. W. Trusty, Refiner, 1940, Vol. 19, pp. 93-6.) (J. Soc. Chem. Ind., Vol. 59, No. 10, Oct., 1940, p. 719.)
72/138	Germany ...	*Ignition Values and Chemical Structure of Liquid Fuels.* (H. Winter and H. Mönnig, Glückauf, 1939, Vol. 75, pp. 907-9.) (J. Soc. Chem. Ind., Vol. 59, No. 10, Oct., 1940, p. 720.)
72/139	U.S.A. ...	*Deterioration Factors in Diesel Lubricants.* (C. G. A. Rosen, Nat. Petrol. News, Vol. 32, No. 18, 1940, pp. R.152 and 545.) (J. Soc. Chem. Ind., Vol. 59, No. 10, Oct., 1940, p. 720.)
72/140	Germany ...	*Relation Between Cetane Number and Starting Characteristics of Diesel Fuels.* (P. Weber, Oel und Kohle, Vol. 36, 1940, pp. 78-89.) (Chem. Absts., Vol. 34, No. 19, 10/10/40, p. 6,791.)
72/141	Great Britain	*Power and Combustion.* (A. C. G. Egerton, Engineer, Vol. 170, No. 4,428, 22/11/40, pp. 326-328.)
72/142	Great Britain	*Power and Combustion.* (A. C. G. Egerton, Engineering, Vol. 150, No. 3,908, 5/12/40, pp. 454-456.)
72/143	Great Britain	*Gas Traction Development.* (Engineering, Vol. 150, No. 3,907, 5/12/40, pp. 456-7.)

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72/144	Great Britain	*Piston Deposits, Ring Sticking, Varnishing and Ring Clogging (Condensed from J. Inst. Petrol.).* (W. A. Gruse and C. J. Livingstone, Engineer, Vol. 170, No. 4,429, 29/11/40, pp. 352-3.) (Abstract available.)
72/145	Italy ...	*Liquefied Methane and Other Gases as Substitutes for Gasoline.* (Grossi, Riv. Ital. Petrolio, Vol. 8, No. 81, 1940, pp. 9, 11, 13, 15, 17, 19.) (Chem. Absts., Vol. 34, No. 21, 10/11/40, p. 7,573.)
72/146	Great Britain	*On the Ignition of Inflammable Gases by Hot Moving Particles.* (S. Paterson, Phil. Mag., Vol. 30, No. 203, Dec., 1940, pp. 437-457.)
72/147	Great Britain	*Lubrication and Wear.* (D. Clayton, Engineer, Vol. 170, No. 4,431, 13/12/40, pp. 383-5.)
72/148	Germany ...	*Comparison of the Behaviour in the Cold of Lubricating Oils from Petroleum and Synthetic Oils.* (R. Heinze and M. Marder, Oel Kohle Erdoel Teer, Vol. 15, 1939, pp. 611-6.) (Chem. Absts., Vol. 34, No. 21, 10/11/40, p. 7,590.)
72/149	Japan ...	*Viscosity Characteristics of Lubricating Oils as Related to their Chemical Structure.* (B. Yamaguchi, Aer. Res. Inst., Tokyo, Vol. 15, No. 192, Aug., 1940.) (Abstract available.)
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72/152	Germany ...	*Meters with Equipment for Continuous Measurement of Quantity.* (W. Brauer, Feinmech. und Präzision, Vol. 46, 1938, pp. 267-8.) (Chem. Absts., Vol. 34, No. 19, 10/10/40, p. 6,491.)
72/153	Great Britain	*High Precision Gauging.* (Engineer, Vol. 170, No. 4,428, 22/11/40, pp. 324-326.)
72/154	U.S.A. ...	*Method for Measuring the Thickness of Non-Magnetic Films (to 10^{-5} of an inch).* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 330.)
72/155	U.S.A. ...	*Contour Finder, developed by Abrams Aerial Survey Corporation (Measures Elevations directly from a Set of Two Aerial Photographs).* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 336.)
72/156	Germany ...	*Measurements of Hardness and Sources of Error.* (H. von Weingraber, Metallwirtschaft, Vol. 19, 1940, pp. 255-60.) (Chem. Absts., Vol. 34, No. 21, 10/11/40, p. 7,232.)
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72/161	U.S.A. ...	*Tensor Gauge.* (Inter. Avia., No. 731, 12/10/40, p. 12.) (Abstract available.)

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72/191	U.S.A. ...	*Trimming Tabs Made of Plastic Material.* (Autom. Ind., Vol. 34, No. 21, 15/10/40, pp. 434-5.)
72/192	U.S.A. ...	*Electroplating Aluminium and its Alloys.* (Autom. Ind., Vol. 34, No. 21, 15/10/40, pp. 435-6.)
72/193	Great Britain	*The Tocco Process for Hardening Steel.* (Engineering, Vol. 150, No. 3,907, 29/11/40, pp. 426-7.)
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ITEM NO.		TITLE AND JOURNAL.
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72/199	U.S.A. ...	*Cold Setting Resin Adhesive (Weldwood Plastic Resin Waterproof Glue).* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 329.)
72/200	U.S.A. ...	*Indium as a Constituent of Bearing Alloys.* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 331.)
72/201	U.S.A. ...	*"Vicalloy" Magnetic Alloy (Co-Va-Fe).* (Sci. Amer., Vol. 163, No. 6, Dec., 1940, p. 340.)
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72/226	U.S.A. ...	*Modern Aircraft Materials and Their Testing.* (K. R. Jackman, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 461-73, 496.) (Abstract available.)
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72/228	Switzerland...	*Hot Strength of Various Aluminium Alloys.* (A. von Zeerleder, Inter. Avia., No. 732, 21/10/40, pp. 1-4.) (Abstract available.)
72/229	Great Britain	"*Tocco*" *Process for Hardening Steel Surfaces.* (Engineering, 29/11/40, pp. 426-7.) (Abstract available.)
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		METEOROLOGY AND PHYSIOLOGY.
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72/239	Great Britain	*Atmospheric Pollution.* (Engineering, Vol. 150, No. 3,906, 22/11/40, p. 415.)
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72/241	Italy ...	*Improved Type of Radio Sonde.* (Inter. Avia., No. 728, 19/9/40, p. 4.) (Abstract available.)
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ITEM NO. TITLE AND JOURNAL.

72/243 Great Britain *The Production of O.M.T. Optical Flats for Test Purposes.* (Engineering, Vol. 150, No. 3,905, 15/11/40, pp. 385-386.)

72/244 Great Britain *Foundations of the Electrical and Mechanical Transmission of Energy.* (W. M. Thornton, Engineer, Vol. 170, No. 4,426, 8/11/40, pp. 302-303.)

72/245 Great Britain *Foundations of the Electrical and Mechanical Transmission of Energy (cont. from p. 303).* (W. M. Thornton, Engineer, Vol. 170, No. 4,427, 15/11/40, pp. 318-9.)

72/246 Great Britain *The Air-Driven Ultracentrifuge.* (F. R. Eirich and E. K. Rideal, Nature, Vol. 146, No. 3,704, 26/10/40, pp. 541-2, 551-2.)

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72/250 U.S.A. .. *Mathematics from the Engineers' Viewpoint. (Paper to Amer. Inst. Mech. Engs.).* (T. von Karman, Engineer, Vol. 170, No. 4,427, 15/11/40, pp. 310-2.)

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72/253 U.S.A. ... *Wearless Tap Washer.* (Sci. Am., Vol. 163, No. 5, November, 1940, pp. 279-80.)

72/254 Great Britain *Statistical Methods in Engineering Practice.* (H. Rissik, Engineer, Vol. 170, No. 4,432, 20/12/40, pp. 389-90.)

PHOTOGRAPHY.

72/255 Great Britain *The Chemistry of Photo-Copying Processes (Part II—The Diazotype Process).* (H. D. Murray, Chem. and Ind., Vol. 59, No. 46, 16/11/40, pp. 769-770.)

72/256 Great Britain *Air Photography Applied to Surveying (Longmans, Green and Co., Ltd.,* 1940, 25/-). (C. A. Hart, Nature, Vol. 146, No. 3,705, 2/11/40, pp. 572-3.)

72/257 U.S.A. ... *Examples of Night Aerial Photography.* (American Aviation, No. 10, 15/10/40, p. 26.)

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72/258 Great Britain *On Maintained Convective Motion in a Fluid Heated from Below.* (A. Pellew and R. V. Southwell, Proc. Roy. Soc., Vol. 176, No. 966, 1/11/40, pp. 312-343.)

WIRELESS AND ELECTRICITY.

72/259 Germany ... *German Radio Equipment.* (Flight, Vol. 38, No. 1,664, 14/11/40, pp. g-h.)

72/260 Germany ... *Electricity Problems in Germany.* (Nature, Vol. 146, No. 3,704, 26/10/40, p. 565.)

72/261 U.S.A. ... *Ultra-Short Wave Transmission over a 39-Mile "Optical" Path.* (C. R. Englund, A. B. Crawford and W. W. Mumford, Proc. Inst. Rad. Engs., Vol. 28, No. 8, Aug., 1940, pp. 360-9.) (Abstract available.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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Note.—As far as possible, the country of origin quoted in the items refers to the original source.

List of Abbreviations of Titles and Journals.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revenue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.

L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes.
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Verceffentlichungen aus dem Gebtete der Nachrichtentecgnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Variation in Velocity Profile with Change in Surface Roughness of Boundary. (W. Jacobs, Z.A.M.M., Vol. 19, No. 2, April, 1940, pp. 87-100. Translation available, No. T.M. 951.) (89/1 Germany.)

The present report deals with a variation of a turbulent velocity profile in flow from rough to smooth wall and vice-versa. Expressions obtained for the shear-stress distribution with respect to the distance from the point of junction of the different roughnesses and from the wall distance, are utilised to ascertain the developing velocity distributions. Under simplified assumptions, the use of these formulæ renders possible the integration of the motion equations for the shear stress. This calculation is carried out and compared with the experiments. Despite the fact that the assumptions in this particular case do not prove to be wholly correct, comparatively good agreement is achieved in the most important region.

Standard Aeronautical Symbols approved by N.A.C.A., May 28th, 1940. (89/2 U.S.A.)

The symbols listed are arranged under the following headings:—

1. General scientific.
2. Aeroplane dimensions.
3. General and applied aerodynamics.
4. Aeroplane dynamics—

   Axes, forces, force coefficients, moments, moment coefficients, velocities, angles, moments of inertia, factors, stability derivatives, stability derivative coefficients.
5. Seaplanes.
6. Airships.
7. Engines and propellers.

8. Rotor planes.
9. Miscellaneous (factors and subscripts).

Abbreviations :—

1. Aeronautical abbreviations used in N.A.C.A. Reports.
2. Laboratory rules about abbreviations.

Review of Researches on the Statistical Theory of Turbulence. (K. Wieghardt, L.F.F., Vol. 18, No. 1, 28/2/41, pp. 1-7.) (89/3 Germany.)

The statistical theory of turbulence has been mainly developed in England and the U.S.A. The author reviews the investigations of Taylor, Karman, Goldstein and others, and concludes that the theory is well adapted to deal with the kinematics of turbulent flow and also furnishes a valuable means for co-ordinating experimental investigations. Dynamic processes, however, cannot as yet be evaluated in a satisfactory manner. Even in the simplest case of isotropic turbulence, the calculation of the so-called correlation curve depends ultimately on fundamental assumptions, such as neglect of inertia terms, or the introduction of equivalent mixing paths, etc. Since, however, the differential equations are derived entirely from the Navier-Stokes and continuity equations, the required solution must be contained amongst the number of possible solutions. What is still wanted is some physical principle by means of which the true solution can be selected.

Two-Dimensional Lift Distribution for Arbitrary Unsteady Motion. (H. Sohngen, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 401-420.) (89/4 Germany.)

Previous investigations on the lift distribution along the chord during unsteady motion are limited to cases of pure vibration, with the special proviso that the motion has been in existence for a considerable period. For the case of an arbitrary unsteady motion, only expressions for the total lift and moment are known. The author considers the lift distribution along the chord in this more general case and his method is applicable to thin aerofoils of small curvature operating at small angles of incidence. Any deformation of the wing with time is assumed to have no effect on the length of the chord. The author also assumes that the wing moves to a first approximation in a straight line with an almost constant velocity V so that the velocities of various points of the wing perpendicular to this direction can be neglected. Special attention is given to the definition of critical velocity and the effect of a free aileron. The same problem has been attacked by a different method by Kussner. L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 355-361, see Abstract 89/21.)

General Aerofoil Theory. (H. G. Kussner, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 370-378.) (89/5 Germany.)

The author establishes a very general integral equation for the aerofoil theory, on the assumption that the disturbances are infinitely small. This equation applies to any type of motion and also holds for compressible fluids. Step by step specialisation of this equation leads to simpler forms such as the Possio, Birnbaum and Prandtl type of integral equation. Special equations are also deduced applicable to the two-dimensional wing with a periodic downwash distribution and to the vibrating wing of large span. The method is finally extended to cover the case of the biplane or the wing with slotted flap.

Calculation of the Pressure Distribution of a Two-Dimensional Aerofoil Undergoing Harmonic Deformations. (L. Schwarz, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 379-386.) (89/6 Germany.)

The method of attacking this problem was first given by Birnbaum in 1924, and extended by Kussner and Cicala in 1936. In the present paper the solution of the Birnbaum integral equation is referred to the known solution by Munk of the steady Prandtl equation of the vortex sheet. The calculation of pressure, lift and moment for a given downwash distribution (wing distortion) can now

be carried out by simple integration without requiring the help of harmonic analysis.

The theory of non-steady motion has thus reached the same stage of development as that of the corresponding steady problem (theory of thin aerofoils).

The Potential Theory of the Vibrating Circular Aerofoil, Part I—Analytical Considerations. (T. Schade, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 387-400.) (89/7 Germany.)

The paper is an extension of a previous investigation carried out by Kinner on the stationary circular aerofoil (Ing. Arch., Vol. 8, p. 47). In the present case, the circular plate, immersed in a uniform airstream, undergoes small vibration, the amplitudes of which are complete function of the second order in x and y. The author determines the pressure distribution on the plate with the help of the Prandtl acceleration potential. A system of linear differential equations is obtained of which the coefficients can be calculated in terms of exponential and Hankel functions. All the necessary equations are given in this analytical part. Numerical calculations will be published subsequently.

The Calculation of Wing Vibrations by the Use of Special Replacement Systems. (W. Biermann and W. Dissecker, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 314-9.) (89/8 Germany.)

Before calculation on wing flutter can be carried out, the behaviour of the wing as regards natural frequencies and vibration forms with the aircraft stationary must be known. Although in most cases actual experiments will be required to settle these points, it is important to be able to predict such results as accurately as possible. The author develops an approximate method for this purpose, in which the wing is replaced as regards its mechanical properties by a special system amenable to simple treatment. It is assumed that the elastic axis is straight and that rotation about the axis under condition of pure twist is not accompanied by any distortion. The equations of motion are then established by means of the following replacement systems:—

1. *Pure bending*, the wing is replaced by a series of rigid links which are coupled statically, additional loads being concentrated at the elastic joints.
2. *Pure torsion*, the wing is considered as made up of a series of sections, each of which has a constant moment of inertia and rigidity. The angle of twist thus varies linearly in each section. Additional masses are again concentrated at the junction of the sections.

The frequency determinants for pure bending and torsion are then obtained from the expressions for kinetic and potential energy in the well known manner from the Lagrange equation. If the wing under consideration has constant bending stiffness EJ and torsional rigidity GJ_d, the equivalent spring constant K at the joints (bending) or equivalent rigidity C of the sections (torsion) is given approximately by $K=EJ/l$ and $C=GJD/l$ respectively, where l=length of link or section, provided the numbers of sections per semi-span exceed 4.

If mass and stiffeners distribution vary along the wing the corresponding expression becomes:—

$$K=1\Big/\int_0^l \frac{dx}{EJ} \quad \text{and} \quad C=1\Big/\int_0^l \frac{dx}{GJ_d}$$

respectively.

Coupled vibration (bending and torsion) are investigated by the Ritz method. The author points out that the method is specially applicable to cases of variable mass and stiffness distribution, since it entails considerable less labour than the usual iteration and integrations method, besides being of sufficient accuracy for most practical purposes. In the case of the wing of a multi-engined aircraft, the authors' method predicted the various experimental "static" fre-

quencies to within 5 per cent. (symmetrical vibration) and 2 per cent. (anti-symmetrical vibrations) respectively.

The Symmetrical Potential Flow of a Compressible Gas about a Circular Cylinder in a Straight Channel (Subcritical Region of Flow). (E. Lamla, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 329-331. Addendum, L.F.F., Vol. 18, No. 1, 28/2/41, p. 37.) (89/9 Germany.)

The corresponding problem for incompressible flow has already been solved by the method of images, *i.e.*, the dipole placed at the centre of the circle is reflected at the walls of the channel and the resultant effect of all images is obtained by summation. The solution is exact, but the profile is not a true circle, although the difference is generally very small. Regarding this solution as a first approximation the author investigates the effect of compressibility to a second approximation, making use of the method of Janzen and Rayleigh. It

U = velocity of incident flow.
a_0 = velocity of sound (medium at rest).
H = width of channel.
R = radius of cylinder.
W_k = maximum velocity at channel wall.
W_p = maximum velocity at cylinder ($\theta = 90$),

the following expressions are obtained:—

$$\frac{W_k}{U} = 1 + \tfrac{1}{4} q^2 + \left[\tfrac{11}{24} q^2 + \tfrac{19}{192} q^4 + \ldots\right] \varkappa^2$$

$$\frac{W_p}{U} = 2 + \tfrac{1}{6} q^2 + \tfrac{1}{180} q^4 + \ldots + \left[\tfrac{7}{6} + \tfrac{43}{72} q^2 + \tfrac{47}{432} q^4 + \ldots\right] \varkappa^2$$

$$\text{where } q = \frac{2\pi R}{H}$$

$$\text{and } \varkappa = \frac{U}{a_0}$$

= Mach number M for very wide channels.

The method only holds for the subcritical region of flow, *i.e.*, the local velocity of sound must not be exceeded at any point.

Experimental Research on Undercarriage Loads and the Efficiency of Shock Absorbers. (V. P. Toulyakov, Aeron. Eng., U.S.S.R., Vol. 15, No. 1, Jan., 1941, pp. 44-52.) (89/11 U.S.S.R.)

Problems investigated are:

1. Value and direction of the forces acting on the undercarriage wheel during take-off, landing and running.
2. Forces acting on the undercarriage struts.
3. Relationship between the force on the shock absorber and the piston stroke.
4. Analysis of the work done in the shock absorber.

The investigation mainly concerns the single-seat fighter type, of weight 1,500 kg., for conditions corresponding to summer and winter landings. In addition a series of tests were made on medium and heavy aircraft.

Results are given in tables and graphs.

Longitudinal Dynamic Stability of an Aeroplane with an Automatic Pilot. (V. A. Kotelnikov, Aeron. Eng., U.S.S.R., Vol. 15, No. 1, Jan., 1941, pp. 27-31.) (89/10 U.S.S.R.)

Theoretical and experimental investigations have been carried out to attempt to explain the effect of the various parameters of the automatic pilot and of the aircraft on the dynamic stability, automatic oscillations and behaviour of the aircraft in a disturbed atmosphere.

A flight test using the automatic pilot A.V.P.-12 comprised determination of longitudinal and lateral dynamic stability and the mean angular deviation of the aircraft from the stable position set by the automatic pilot. In addition an experiment was carried out on a specially constructed test stand to study the natural oscillations of a system stabilised by a course stabiliser A.V.P.-12.

The theoretical investigation consisted in solving the system of linear differential equations for the motion of the stand or of the aeroplane and the simplified non-linear equations for the motion of the automatic pilot. In the case of the non-linear equations the regimes of auto-oscillation were determined by assuming that the system moves according to a sine law. In establishing the equations of motion of the auto-pilot, the operation was assumed to be imperfect on account of the finite velocity of the control surfaces and the delay in the air effect.

Airscrew Development for Maximum Speeds. (Inter. Avia., No. 750, 13/2/41, pp. 1-3.) (89/15 Switzerland.)

An increase in the number of airscrew blades would seem to be the easiest means at present to increase the performance of airscrews. No general rule can be established for the number of blades to be employed; the number must be determined in each individual case for each aeroplane or engine. The reduction gear ratio of the engine must be carefully adapted to the number of airscrew blades; it can be calculated that the 2,000 h.p. engine of an aeroplane having a speed of more than 385 m.p.h. at 20,000 ft. must be reduced to 800 r.p.m. for a three-blade airscrew to 925 r.p.m. for one with four blades, and to 1,150 r.p.m. for one with six blades, in order to obtain the optimum propulsive efficiency. The three-blade airscrew is still retained to-day in most cases even though the six-blade propeller has two important advantages: Smaller diameter and lower weight. The four-blade airscrew, such as the Curtiss Electric design fitted to the American Martin B-26 twin-engined bomber, is an excellent compromise between the three- and six-blade versions.

By extensive isolation of the airscrew from the vibrations created by the engine it is hoped to attain a considerable saving in building material and weight. A minor improvement in the static thrust is obtained by the fitting of cuffs to the blade shanks to give the latter an airfoil shape, and it seems probable that the future airscrews designed for high engine powers will have to abandon the present narrow blades in favour of airscrew blades of greater width.

U.S.A. Airport Statistics. (Inter. Avia., No. 750, 13/2/41, p. 16.) (89/17 U.S.A.)

On January 1st, 1941, there were 2,656 airports, landing fields and seaplane bases in the United States and Alaska compared with 2,451 at the beginning of 1940. These included 788 municipal and 496 commercial airports, 289 Civil Aeronautics Administration Intermediate Fields, 507 Auxiliary Fields, 21 Naval Air Stations, 69 Air Corps Fields, and 161 Miscellaneous Government private and state airports and landing areas. Of these 2,331 fields, 776 were either fully or partly equipped for night flying. In addition, there were 325 seaplane bases and anchorages on January 1st, including 15 equipped for night operation, compared with 171 at the beginning of 1940. This number is composed of Army, Navy, Coast Guard and Marine Corps bases, as well as commercial installations. Six states and the territory of Alaska have more than 100 fields and airports, as follows:—California 174, Texas 146, Pennsylvania 107, Florida 122, Michigan 116, Ohio 105, Alaska 129.

Fletcher Trainer in Plastic Plywood. (Inter. Avia., No. 750, 13/2/41, p. 6.) (89/16 U.S.A.)

The machine is a two-seater cantilever low wing monoplane of plastics plywood construction and has the following characteristics: The fuselage is of conventional semi-monocoque construction, the stressed skin consists of a new two-ply

birch plywood, the sheets of which are laid up in such sizes that a single sheet goes completely around one half each of the fuselage shell which is divided along a horizontal plane. A feature of the birch plywood is that the angle of the plies is developed precisely to meet most efficiently the normal loads imposed on the structure, so that a kind of geodetic design results. The two wing halves are covered by the plywood skin in a similar manner; a single sheet goes completely around either wing panel from root to tip and from trailing edge around the leading edge back to the trailing edge; the skin is attached to the wing structure by a secret bonding process using pressure and heat.

Characteristics and Performance.—Span, 30 ft.; length, 21.5 ft.; with a power plant of 130 h.p.; gross weight, 2,100 lb.; fuel capacity, 30 U.S. gals.; maximum speed, 135 m.p.h.; landing speed, 58 m.p.h.; rate of climb, 730 ft./min. with 285 h.p.; engine gross weight, 2,500 lb.; fuel capacity, 50 U.S. gals.; maximum speed, 175 m.p.h.; landing speed, 65 m.p.h.; rate of climb, 1,350 ft./min.

Photo Lofting in the U.S.A. (Inter. Avia., No. 747, 30/1/4, pp. 9-10.) (89/18 U.S.A.)

For the manufacture and assembly of individual construction elements of mainly irregular curvatures, such as ribs, transverse frames and bulkheads, which in the finished aircraft determine the curved surfaces, the aircraft industry has for a long time employed a method it borrowed from the shipbuilding industry. For these parts full-size drawings were made and traced on metal sheets by hand which afterwards were cut out and used as templates. In order to simplify this complicated and lengthy operation which caused a great loss of time between the design and the quantity production of the aeroplane, an engineer of the Lockheed Aircraft Corporation has developed a method which has already been adopted by several aircraft firms. The engineering drawings are photographed on 14 by 17 in. plates and subsequently projected to the full size of the aircraft parts on sensitised template metal sheets by means of a projector camera. Immediately afterwards the drawing is again projected in full size on a sensitised tracing cloth which is used for the preparation of the blueprints; in the meantime the template is cut out and can immediately be employed in the shop. In addition to a great saving of time, the photoloft process has the advantage of eliminating a whole series of possible sources of error.

The Effect of Centrifugal Force on the High Order Bending Vibrations of Airscrews at Various Angles of Blade Incidence. (J. Meyer, L.F.F., Vol. 18, No. 1, 18/2/41, pp. 24-5.) (89/19 Germany.)

On the assumption that bending vibrations occur only transversely to the plane of rotation the author has shown in a previous paper (L.F.F., Vol. 16 (1939), p. 429) that the natural frequencies λ can be represented by the equation

$$\lambda^2 = \lambda_0^2 + C W^2$$

where λ_0 = bending frequency of stationary blade.
W = angular velocity of blade.
C = constant.

The values of C for the first and second harmonic were calculated by the author for zero blade setting and various mass distributions along the blade, utilising the analogy of a rope undergoing vibrations in a centrifugal field of force. Modern airscrews have, however, considerable blade setting and in the present paper the author investigates the effect of this. It appears that the variation of C with blade setting is given by the equation::—

$$C_d = C - \sin^2 d, \text{ where } d = \text{blade setting angle.}$$

The relationship, however, only holds for the higher harmonics for which the vibration form of the blade approximates to that of a rope vibrating in a centrifugal field of force, which analogy forms the basis of the calculations.

The Vibration of a Wing Fitted with an Aerodynamically Balanced Aileron. (H. G. Kussner and L. Schwerz, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 337-354.) (89/20 Germany.)

In a previous contribution (L.F.F., Vol. 13, pp. 410-427) the principal author of the present paper has already dealt with the two-dimensional problem of the vibrating wing fitted with an aileron swinging about its leading edge. In the practical case the aileron axis of rotation is placed farther back (aerodynamic balance) or tabs are fitted to the trailing edge of the control surface. The latter problem is relatively simple (since it merely entails providing the equivalent flat plate of the previous investigation with two sharp bends instead of one) and has been solved by Dietze (L.F.F., Vol. 16, pp. 84-96). The case of the aerodynamically balanced aileron (axis of rotation behind leading edge) presents, however, some difficulties, since now we have two plates vibrating independently. The author shows how the practical case can be reduced to an equivalent system with 6 degrees of freedom for each of which he determines the forces, moments, pressure distribution and aerodynamic co-efficients. The final results for the complete wing are then obtained by superposition, the requisite constant being given in numerous tables.

The Two-Dimensional Problem of a Wing Undergoing Arbitrary Displacement in "Gusty" Air. (H. G. Kussner, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 355-361.) *The Evaluation of U (s) and U2 (s) Functions for Large Values of s.* (L. Schwarz, L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 362-9.) (89/21 Germany.)

Classical aerofoil theory deals with the case of uniform motion of the wing in a fluid at rest. The theory was later extended to cover non-steady motion (vibration) the surrounding fluid being still at rest. This problem is of interest (wing flutter) and the two-dimensional case may be considered as solved.

In practice the air is not generally at rest but may be turbulent or gusty, and this may effect the wing loading appreciably if the speed or size of the wing is considerable.

In a previous paper (L.F.F., Vol. 13, pp. 410-424) the author has shown that the most general two-dimensional solution can be converted by means of the Laplace Transformation into the special case of harmonic vibration and represented by known functions. The integral expression for the pressure jump at the wing hold for any arbitrary motion or deformation of the wing surface in either quiescent or "gusty" air. In the original paper mentioned above, the author considered the case of a wing entering the confines of a jet. As was pointed out subsequently by Karman and Sears (J. Aeron. Sci., Vol 5, pp. 379-390) there are several errors in this first paper which have been corrected in the present investigation. At the same time the function entering into the pressure jump integrals have been re-calculated and tabulated. Details of this calculation are given by Schwarz in an addendum to this paper (L.F.F., Vol. 17, No. 11-12, 10/12/40, pp. 362-369).

Oil Engine Design—The Combined Effect of Swirl and "Squish" (Radial Flow) on Combustion. (Automobile Engineer, Vol. 31, No. 407, Feb., 1941, pp. 63-64.) (89/22 Great Britain.)

It is well known that efficient combustion in a compression ignition engine is largely a question of proper control of the motion of the air in the cylinder with respect to the fuel spray. Rotary motion is termed swirl and can be produced in a variety of ways, such as tangential air inlets, masked valves or control of air flow from cylinder into the combustion space proper by appropriate design of transfer passages.

In the majority of injection engines the combustion chamber is in the form of a recess in the cylinder head or piston crown. The clearance between the piston in its T.D.C. position and the annular space surrounding the recess is very small and as a result there is a pronounced radial flow of air into the com-

bustion space as the air is " squeezed " out during the last portion of the stroke. This secondary air movement may influence the rotary motion or swirl produced previously and the term " squish " has been coined by Ricardo to denote this effect. The radial streams from opposite sides of the annulus will meet and be deflected upwards into the combustion space, producing a kind of toroidal motion. The problem has been analysed by C. B. Dicksee in his book " The High Speed Compression Ignition Engine," and it appears that the " squish " velocity towards the end of the stroke may be of the order of 50-100 feet/sec., depending on engine r.p.m., ratio of diameter of opening into the combustion space to that of the cylinder, compression ratio and clearance. The last factor has a very pronounced effect and quite a small change in the cylinder head gasket will alter the nature of the " squish " completely. In conclusion, it must not be overlooked that although the " squish " velocity may not appear to be very high, the corresponding pressure head may be of the order of 70 lb./sq. in. on account of the high density of the air during this portion of the cycle.

Comparison of Direct Injection Engine (Ju 211D) and Carburettor Engine (Rolls-Royce Merlin X) as regards Performance at Altitude. (Aeroplane, Vol. 60, No. 1,554, 7/3/41, pp. 289-92.) (89/23 Great Britain.)

Tests have been made on two Junkers Jumo 211D engines having direct petrol injection equipment, the nearest British equivalent, the Rolls-Royce Merlin X, being used for comparative tests. Fuel consumption curves were obtained at three different speeds. In view of the difference in dimensions of the two motors the consumption tests on the Merlin were not made at the same crankshaft speeds as the Jumo engine, but at speeds which gave the same piston speeds. Thus the Merlin had to be run 8.25 per cent. faster and therefore at a slight disadvantage. Maximum powers available in level flight were also compared. Specific fuel consumptions of the two types of engine were practically the same except at the lowest speed and power conditions, at which that of the Merlin was 4 per cent. inferior. However, the consumptions given by the automatic mixture regulator are lower for the Merlin over the whole range of speeds than the comparable consumptions for the Jumo, the advantage over the whole speed range being about 7 per cent. Power curves show that at heights above 16,000 feet the Merlin has advantages in power. The system of fuel injection requires a much more complicated mechanism than is required by a carburettor engine. The Jumo injection system comprises some 1,576 parts and weighs approx. 60 lbs (excluding the supply pump) compared with 433 parts and a weight of only 25 lb. for the Merlin carburettor (including Amal valve and fuel pipes). It is concluded that the simplification of the controls made possible by fuel injection pumps is nullified by this increased complication of the complete system, and no greater fuel economy is shown. Good distribution of air to the individual cylinders, which is possibly more important than fuel metering in obtaining low level consumption, cannot be controlled by injection pumps. With fully supercharged carburettor engines the fuel distribution is known to be good and defects such as liability to freezing and cut out during aerobatics can be rectified by suitable design. It is concluded that in engines of conventional design nothing would be gained by use of injection pumps.

Investigation of the Effect of Excess Air Coefficient on the Indicated Efficiency of a Diesel Engine. (T. M. Melkumov, Aeron. Eng., U.S.S.R., Vol. 15, No. 1, Jan., 1941, pp. 53-64.) (89/24 U.S.S.R.)

Diesels of different construction may have different indicated efficiencies at equal values of the excess air coefficient. , Consequently curves of the type $\eta_i = f(\alpha)$, where η_i values are given as percentages and α in absolute units cannot be applied universally and may be used only for narrow ranges for one type of engine. In particular, the N.A.C.A. graph for aero Diesels is not satisfactory. A universal characteristic for all Diesels of any type or speed may be obtained

by expressing the relationship between the relative value of η_i to the corresponding relative value of α. To do this we may take any value of α for one engine and for other engines the values of α which give an identical value for $d\eta_i/d\alpha$. In practice fully satisfactory results are obtained by plotting graphs for

$$\frac{\eta_i}{\eta_{iE}}\% = f\left(\frac{\alpha}{\alpha_E}\right)$$

where α and η_i are the prevailing values of excess air coefficient and corresponding indicated efficiency, α_E is the value of the excess air coefficient giving minimum fuel consumption and η_{iE} the corresponding value of the indicated efficiency.

The analysis given does not permit practical calculation of the characteristics of a new engine since for the latter α_E is unknown. Accurate determination of α_E for different working conditions and evaluation of the practical application of the method will be a subject for further research.

Pressure and Temperature Measurement in Supercharger Investigations. (A. Franz, Jahrbuch der Deutschen L.F.F., Vol. 2, 1938, pp. 215-8.) (Available as M.A.P. Trans. 1,095.) (89/27 Germany.)

With the further development of the supercharger requirements with regard to measuring accuracy increase while at the same time the conditions under which the measurements must be carried out become more difficult. The present paper is a contribution toward the improvement and refinement of the measuring methods. For pressure measurements some suggestions are made with regard to design and location of the measuring stations. The question of temperature measurement in rapid air flow is discussed, new instruments for the direct measurement of the temperature in the rapid air stream are described and the results obtained with the various instruments presented.

The more nearly the attainable limits are reached in the development of the supercharger the higher become the requirements that must be satisfied by the measurement procedure. At the same time the conditions under which the measurements must be carried out become much less favourable as, for example, in pressure and temperature measurements for which the rise in the flow velocities have considerably increased these difficulties.

Supercharged Aircraft Ignition Harnesses (Ventilation of Contaminated Air) (with discussion). (C. E. Swanson, J.S.A.E., Vol. 48, No. 3, March, 1941, pp. 107-116.) (89/28 U.S.A.)

The supercharged aircraft ignition distribution system is a system which supplies air free from harmful ingredients and at pressure maintained in considerable excess of that of the surrounding atmosphere to the space within the spark plug shield chambers, and is a system which provides ways and means by which the contaminated air may be removed from these regions. It is a feature of the system to utilise for the conduction of this air the type of ignition harness which already constitutes a conduit system to the spark plugs because, through such a type of harness clean air can be transmitted to and into all the spark plug shield chambers and adjacent spaces without adding tubing or additional conduit of any sort. The very important consideration of providing means for the escape of contaminated air from within is accomplished by utilising for this purpose the inherent leaks of the harness or, if these prove insufficient, to provide such leaks purposely by drilling holes or otherwise making openings in the shielding.

After describing the system in detail, a summary is made of various other designs of harnesses which have been set forth in an effort to eliminate the ignition distribution problem and, it is pointed out wherein each has its weaknesses.

In support of the contention that supercharged harness makes possible complete relief from the troubles associated with harness contamination a perfect service record of 5,000,000 engine miles is cited.

Problems relating to the Control of Flow in Engine and Cabin Superchargers. (N. C. Price, J.S.A.E., Vol. 48, No. 3, March, 1941, pp. 118-124.) (89/29 U.S.A.)

Comparisons are drawn between engine supercharger flow-control problems. Some new methods of obtaining efficient flow control are discussed. Interdependent factors existing between flow control and impeller speed control must be recognised.

It is pointed out that design features in the supercharger should be correlated closely with the type of control applied.

Effects arising from the connection of superchargers to receivers of large volume are presented. Necessity for regulation of flow for pressure cabins requires the solution of numerous new problems. The advantage of simultaneous design of the supercharger and controls, and the desirability of integral supercharger and control units, are stressed. It has been necessary to overcome many mechanical problems in order to produce units of a type suited for pressure cabin operation. Typical control constructions are described.

A New Method of Determining the Gas Temperature Cycle in a Four-Stroke Spark Ignition Engine. (H. Graff, L.F.F., Vol. 18, No. 1, 28/2/41, pp. 8-17.) (89/30 Germany.)

The method depends on the measurement of the radiation of the resonance line of potassium, obtained by adding a small proportion of potassium alcoholate to the engine fuel (leaded petrol). The radiation is measured by means of a gas-filled infra red photocell, the current being amplified sufficiently for direct recording by means of a cathode ray oscillograph. Details are given of the experimental arrangement and the means adopted for co-ordinating current and gas temperature values. Direct comparison of the temperatures obtained by the photocell with those obtained by the well known spectrum line reversal method shows very good agreement and furnishes proof that neither variation in gas composition nor changes in pressure have any material effect on the intensity of the radiation of the resonance line. The method appears to have an accuracy of about 1 per cent. for temperature in the neighbourhood of 1,800°C. abs. The main difficulty is due to deposits accumulating on the quartz windows fitted in the engine combustion space. An extension of the method which does not suffer from this defect is being investigated.

Damping of Torsional Vibrations by Means of Electrically Coupled Masses with Non-Linear Spring Constants. (K. Maier, L.F.F., Vol. 18, No. 1, 28/2/41, pp. 18-23.) (89/31 Germany.)

It has been observed in practice that dampers with non-linear elastic constants do not experience an increase in temperature comparable with the vibrational energy destroyed. Hence the common explanation that such fittings work mainly by internal friction has to be discarded and a close study of the system appeared to be justified. The analytical solution of a single oscillating mass with non-linear elastic constants undergoing either damped or undamped forced vibrations is already known. An extension of the problem to multi-mass systems leads, however, to great mathematical difficulties. For this reason the authors investigated the problem experimentally and showed that the damping effect is mainly a question of tuning. The best results are obtained if both mass and elastic constant of damper are chosen so as to produce maximum changes in the natural frequencies of the whole system with change in " equivalent " stiffness due to deflection of damper. If the tuning is, however, such that an increase in the " equivalent " stiffness produces only a slight increase in the natural frequency of the system, the damper works mainly by internal friction of the spring system.

Graphical Determination of the Discharge Process of a Gas from a Container. (O. Lutz, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 332-5.) (89/33 Germany.)

The author investigates the discharge process of hot exhaust gas from an engine cylinder, taking into account the motion of the piston and the variable

section of the discharge passage (exhaust valve). Intensive use is made of $J-S$ tables (J=enthalpy, S=entropy) recently published by the author.

The calculation is carried out step by step, at approximately 10-crank angle intervals in the critical and five intervals in the sub-critical flow region. The values for the contraction coefficients at the valves are taken from experiments carried out under steady flow conditions. The effect of unsteadiness of flow on these coefficients will be discussed in a subsequent report. The method is illustrated by a worked out example.

The Development of Direct Fuel Injection for Spark and Compression Ignition Engines by the Junkers Works during the Period 1916-1924. (A. Lichte, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 291-296.) (89/32 Germany.)

Experiments on direct fuel injection for c.i. engines were initiated by the late Prof. Junkers as early as 1913, and interesting abstracts from the note-book of his assistant, Dr. Mader, are given. It is worthy of note that the so-called "fish tail" jet (a flat fanwise distribution of the fuel) already dates from this period. During the 1914-1918 war considerable work was done on spark ignition two-stroke engines operating with fuel injection. Lubrication troubles due to the nature of the fuel (petrol) were overcome by utilising a stepped pump cylinder and oil seal. In a later form, the pump piston was given rotary as well as reciprocating motion. The experiment gave promising results, but all work of this nature had to be stopped after the armistice. Subsequent work was concentrated on the compression ignition engine and by 1924 the pump element with slanting piston crown and control by rotation (as now generally adopted) had been evolved. In 1933, petrol injection for spark ignition was once more taken up, and it is stated that the rapid development of the German aircraft engines using this method of fuel supply must be largely credited to the valuable experience gained by the Junkers works in their early researches.

Some Notes on the Engine Airscrew Combination. (W. Hoff, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 299-305.) (89/34 Germany.)

It has been customary for some time to express both the power absorbed by an airscrew and the thrust produced in terms of certain non-dimensional coefficients. The work output of the engine, on the other hand, is usually expressed in dimensional form. Now both these constituents of the aircraft power plant obey different laws. Provided, however, the performance of the airscrew and engine is known at different altitudes and r.p.m. it is possible to correlate these two components by expressing the engine output also in non-dimensional form. In this case neither the absolute power of the engine nor that of the screw need be known. The following cases are treated in detail:—

1. Airscrew with fixed pitch.
2. Airscrew with pitch adjusted for maximum airscrew efficiency.
3. Constant speed V.P. airscrew.
4. V.P. airscrew, r.p.m. of screw diminishing as flight speed increases.

By means of tables and curves, it is possible to select optimum operating conditions in each case.

Lubricating Oils for Internal Combustion Engines. (L. H. Mulit, F. W. Kavanagh, J.S.A.E., Vol. 48, No. 3, March, 1941, pp. 98-106.) (89/35 U.S.A.)

Some of the performance characteristics of lubricating oils, such as limiting cranking temperatures, oil mileages, and gear shifting temperatures, can be predicted from viscosity determinations, but the other items of interest to the users, such as stability, ring sticking, gumming and wear, cannot be predicted from inspections. The trend of engine design, in both the petrol and diesel fields, has resulted in an increase in the mechanical and thermal loads imposed on the lubricating oil and, in some services, such as diesels and aviation engines, satisfactory operation can be obtained only by the use of compounded oils.

Such oils cannot be judged by simple laboratory tests and should therefore be selected on a basis of their performance in full-scale engines.

Compounded oils cannot be reclaimed successfully. This is due to the fact that, in reducing gummy deposits, the compounding materials are consumed and, since the reclaiming operation cannot supply additional compounding, the reclaimed oils are always inferior to the fresh oils. Compounded oils also tend to form a more stable foam than ordinary mineral oils, and the presence of the foam is more noticeable because of its persistence, although the actual amount of foam may be only slightly greater than with an uncompounded oil.

It should be emphasised that the addition of small percentages of compounding material to an oil has a large influence on its service performance; yet it causes almost no change in the normal inspections, and these values are therefore meaningless with respect to the performance characteristics of the lubricant.

Oxidation of Lubricating Oils (Apparatus and Analytical Methods). (M. R. Fenske, Ind. and Eng. Chem. (Analytical Ed.), Vol. 13, No. 1, Jan., 1941, pp. 51-60.) (89/36 U.S.A.)

An apparatus and procedure are described which permit determination of the rate of lubricating oil oxidation. Studies are usually made over the range 130° to 180°C. using oxygen in a circulatory system. Methods have been developed for the determination of substantially all the volatile and non-volatile end products of the reaction.

Ninety to 100 per cent. of the oxygen absorbed by various oils has been accounted for in the products determined. The chief product is water, which accounts for 40-60 per cent. of the reacting oxygen. Soluble saponifiable materials represent another considerable portion, while carbon dioxide, carbon monoxide, volatile acids, fixed acids, and precipitable products account for the remainder.

The analysis of insoluble materials produced by laboratory and engine oxidation indicates these to be relatively highly oxygenated materials (14-24 per cent. oxygen) produced by polymerisation or condensation of the oxidised oil. Molecular weights and elementary analyses suggest certain empirical formulas for the insoluble bodies.

The oxidation of several commercial light oils shows that rates of oxidation vary widely and that induction-type oxidation curves may be common. In general, these results show the widely different oxidation characteristics existing in oils, and that much of the oxidation mechanism remains to be understood before corrective measures are generally applicable.

Standards for Discharge Measurement with Standardised Nozzles and Orifices (German Industrial Standard 1952—4th edition). (V.D.I.-Verlag, G.m.b.H., Berlin, 1937. Translation available as T.M. 952.) (89/37 Germany.)

EXTRACTS FROM PREFACE TO 3RD EDITION (1935).

The constructions of the standards is now clearly divided into definitions of standardised designs of throttling devices and their standardised installations, and guiding information which is to be considered when deviations from the standardised manufacture or the standardised installation occur. Through this division the application of the standards in practice should be simplified and, at the same time, their range of use is extended to those cases that are to be handled with low requirements for accuracy.

The discharge coefficient of the standard nozzle has been newly investigated for ratios of areas $m>0.5$ up to $m=0.64$. These investigations have shown that the discharge coefficient for $m>0.35$ are lower than given in the first and second editions, and that the basic tolerance for m is to be increased for high values of m.

The international standards of the I.S.A. (International Federation of National Standardising Association), suggested by the I.E.C. (International Electro-

technical Commission), adopted at the last meeting at Stockholm, September, 1934, are based principally on the same German investigations as those underlying the VDI Standards. In this way, agreement of the VDI Standard with all essential provisions of the I.S.A. Standards is guaranteed at the start. In particular, the designs of the German standard nozzle and standard orifice and also the discharge coefficients are the same as those of the I.S.A. nozzle and the I.S.A. orifice.

PREFACE TO 4TH EDITION (1937).

In the fourth edition of the Standards, the equations and make-up used in the third edition are essentially unchanged. From experience and on the basis of new tests, a few but quite important changes, as well as several corrections and additions, have been made. These are concerned principally with the dimension of the cylindrical parts s' of the standard orifice and the displacement of the tolerance limit in the direction of higher Reynolds numbers.

A short section on the permanent pressure loss is given again, as in the second edition. Also the section on the conditions when using non-standard pressure taps is treated more fully as compared with the second edition, in order to enable correlation with foreign investigations, which are frequently conducted with non-standard pressure taps.

Corrections on the Thermometer Readings in an Air Stream. (E. J. Vanden Maas and S. Wynia, National Luchtvaart Laboratorium, Amsterdam, No. 8, 1939, Report V. 834, pp. 28-33. Translation available as T.M. 956.) (89/38 Netherlands.)

The reading of a thermometer exposed to an air stream is affected by adiabatic compression, friction in boundary layer and time lag. If the thermometer is small enough, stagnation temperature can be measured directly and friction is negligible.

In the case of the distant reading mercury thermometer employed by the N.L.I. both friction and compression are operative and the total correction $\Delta\theta_a$ in degrees Centigrade is given by the equation:—

$$\Delta\theta_a = -3.86 \times 10^{-5} (\rho_o/\rho_H) V_q^2$$

where V_q = dynamic velocity in km./h.
ρ_o = standard ground density.
ρ_H = density at altitude corresponding to V_q.

Some values are given in the table below.

Dynamic Velocity Km./h.	$\Delta\theta_a$ 100	200	300	400
Altitude 0 ...	−0.39	−1.54	−3.48	−6.17
3,000 m. ...	−0.52	−2.08	−4.68	−8.32
6,000 m. ...	−0.72	−2.87	−6.45	−11.5
9,000 m. ...	−1.01	−4.06	−9.12	−16.2

Corrections for lag will vary from case to case and must be determined separately.

Gas Carburising by the Hypercarb Process. (W. A. Darrah, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 54-9.) (89/40 U.S.A.)

The Hypercarb process serves to apply a controlled high-carbon case on steel articles, which greatly increases the hardness and wear resistance of the surface. The process depends on treating steel articles at controlled temperatures for a controlled time by an atmosphere containing hydrocarbons and carbon monoxide in definite percentages.

The articles leave the furnace clean and free from carbon scale or soot so that no cleaning is necessary. The process is controllable and economical, and has a wide commercial application.

Modern Aircraft Materials and Their Testing. (K. R. Jackman, J.S.A.E., Vol. 47, No. 5, Nov., 1940, pp. 461-73 and 496.) (80/39 U.S.A.)

The commonest steels used for the highly stressed parts of aircraft (landing gears, engine supports, etc.) are as follows:

MATERIAL. No.	Specifications. Army.	Specifications. Navy.	Form	Specific Gravity. D	Weight lbs. cu. in.	TENSION. Ultimate T	Ultimate T/D	Yield. Y ÷ 10^3	Yield. Y/D	Mod. of Elas. E ÷ 10^6	Mod. of Elas. E/D	Elong. % in 2in.	SHEAR. Ultimate S ÷ 10^3	Ultimate S/D	Modulus of Rigidity. $G \div 10^3$	Fatigue Limit. ÷10^4	Cost. $/lb.
STEEL ALLOYS																	
1025	57-107-9B	46-S-22	Bar	7.8	.28	55	7.1	36	4.6	28	3.6	22	—	—	—	—	—
2330	57-107 17b	46-S-21b	Bar	7.8	.28	125	16.0	1100	12.8	29	3.7	17	—	—	—	—	.15
X4130	57-107-19b	46-S-23E	Bar	7.8	.28	150	19.2	135	17.3	29	3.7	18	100	12.8	11	78	.15
4345	11062	46-S-28	Sheet	7.8	.28	230	29.5	220	28.2	30	3.9	4	—	—	11	95	—
STAINLESS STEEL ALLOYS																	
18-8	57-136-9	47-S-19	Sheet	7.8	.28	80	10.2	35	4.5	26	3.3	40	70	9.0	—	30	70
18-8	11068	47-S-21-½H	Sheet	7.8	.28	150	19.1	110	14.0	26	3.3	10	100	12.8	—	35	70
18-8	10079	46-S-18 1C	Bar	7.8	.28	120	15.3	60	7.7	30	3.9	15	—	—	—	—	55
18-8	10079	46-S-18-7E	Bar	7.8	.28	1100	12.8	50	6.4	29	3.7	28	—	—	—	—	55
16-2		M-286	Bar	7.8	.28	175	22.4	135	17.2	30	3.9	13	—	—	—	—	50

S.A.E. 4345, a Ni-Cr-Mo steel, suitable as substitute for the usual Cr-Mo steel, has good depth-hardening qualities, making it suitable for high-strength forged fittings. It may be heat-treated to over 200,000 lb./sq. in., and the excessive hardness produced by welding can also be neutralised by heat treatment. Scaling during heat- treatment is now largely overcome by use of an anti-scaling compound "Galvo."

Stainless steels are divisible into two groups:—1, Those not suitable for heat-treatment but which obtain their qualities from cold-working; and 2, those that can be heat-treated. The first group, which includes the "18-8" types, contain low carbon, 17-25 per cent. Cr. and 7-13 per cent. Ni. and are usually non-magnetic. The second heat-treatable group consists of magnetic steels containing 12-18 per cent., approximately 2 per cent. Ni. and up to 1 per cent. C.

The conventional heat resisting steel for aero-engine exhaust collectors is a titanium stabilised 18-8 product, Navy designation "47S19."

Particular uses and treatments of the various grades of aircraft steels are briefly mentioned.

Increasing the Ductility of Welds. (Dawson and Lytle, Steel, 20/1/41, pp. 62-4.) (89/41 Great Britain.)

A study has been made of the effect of heat treatment on the physical properties of oxyacetylene welds. The results recorded indicate that the ductility of the weld metal, as indicated by elongation and reduction of area under tensile load, can be improved 30 to 50 per cent. by treatment at lower temperatures than are ordinarily employed for stress-relieving treatment. According to the authors this improvement takes place in low alloy steels as well as in carbon steels.

(Absract supplied by Metropolitan-Vickers Research Department.)

Electromagnetic Stirring Action in a Spot Weld. (Unger, Matis and Knoske, Welding Journal, Jan., 1941, pp. 42-7.) (89/42 Great Britain.)

The authors maintain that when the metal in a spot weld becomes molten, electromagnetic forces acting on the liquid create a violent stirring action. Macro-photographs taken from welds made between a low alloy high tensile steel and stainless steel are produced in support of this statement. A method is also described by which satisfactory welds can be made without the melting and mixing action. The physical properties of the two types of welds are compared.

(Abstract supplied by Metropolitan-Vickers Research Department.)

Creep Strength of Stabilised Wrought Aluminium Alloys. (W. Muller, Aluminium Industry A.G., Neuhausen, Rept. 536, Dec., 1939. Translation available as T.M. 960.) (89/46 Switzerland.)

The tests were carried out on the following alloys: Anticorodal, Avional D, Peralumin 2, Peralumin 7. For comparison Aluminium (99.5 per cent. pure) was also included. In each case, the original extrusions were redrawn cold to app. 20 mm. diameter and stabilised. The reason for utilising such soft materials in the preliminary tests was to simplify the problem and obtain limiting values which might occur in practice after prolonged periods of reheating.

Further tests on age hardened and cold formed alloys are in hand.

The creep strength was investigated both by the Rohn method (600-700 hours under steady load, the temperature being automatically controlled by the yield so that the total plastic flow does not exceed admissible bounds) and by the shortened V.D.M. method (strain rate between 25th and 35th hour 1/1000 per cent. per hour, total strain after 45 hours not exceeding 2 per cent). The values obtained by the two methods were found to be in reasonable agreement, the V.D.M. method giving slightly higher values in all cases with the exception of anticorodal.

The hot yield point (.2 per cent. permanent set) as obtained from the machine diagram in the normal tensile test (period 2-5 minutes) is appreciably above the creep strength at all temperatures in excess of 100°C. Below this temperature, however, the creep strength tends to exceed the yield point, probably due to strain hardening of the material during the creep tests.

The most interesting point brought out in the present tests is the great importance of ground vibrations in lowering creep strength values. Such vibrations may easily lower the creep strength by as much as 50 per cent. and the specifications for such tests should, therefore, be redrawn to ensure proper insulation of the test machines (rubber blocks, etc.)

The following table gives the creep strength (C.S.) and (static yield) points (Y.P.) of the materials tested (Kg./mm.^{2}).

	20°C.		100°C.		200°C.		400°C.	
	YP.	CS	YP.	CS.	YP.	CS.	YP.	CS.
Aluminium ...	1.5	3.3	1.4	1.5	1.2	0.9	0.3	0.2
Anticorodal ...	6.5	(8.0)	5.1	4.3	3.3	2.3	1.3	0.5
Avional ...	9.8	(12.0)	9.0	9.3	6.3	4.8	1.8	0.9
Peralumin 2 ...	7.9	(9.0)	7.7	7.4	6.8	2.8	0.8	0.2
Peralumin 7 ...	12.9	(14.0)	12.6	13.4	10.7	1.2	0.4	0.1

Effect of Low Temperature on the Properties of Aircraft Metals. (S. J. Rosenberg, Bur. Stan. J. Res., Vol. 25, No. 6, Dec., 1940, pp. 673-701.) (89/43 U.S.A.)

The effect of sub-zero temperatures down to −78C. was determined upon the tensile, hardness, and impact properties of metals commonly used in aircraft construction. These materials were divided into three general groups: (1) Ferritic steels, (2) austenitic stainless steels and nickel alloys, and (3) light-metal alloys.

The tensile properties and the hardness of all materials were generally improved at low temperatures. The resistance to impact of the ferritic steels decreased generally as the test temperature was lowered, the rate and nature of the decrease being dependent upon the type of steel and its treatment. The impact resistance of the austenitic stainless steels and the nickel alloys was not deleteriously affected and they were considered best adapted for service at low temperatures. The impact resistance of the aluminium-base alloys was not decreased; the impact resistance of the wrought magnesium-base alloys was adversely affected by the low temperatures, while that of the cast magnesium-base alloys was not. These last-named materials were, however, extremely brittle even at room temperature.

Arc Welding of High Tensile Alloy Steels. (Rollason and Others, Transactions of the Institute of Welding, Jan., 1941, p. 21.) (89/47 Great Britain.)

It is stated that the problem of welding high tensile steels lies in preventing hot cracks in the weld and cold cracks in the hardened base plates. The report is divided into three parts dealing with the cracking problem with special reference to thermal characteristics, base metal cracking and the effect of delayed cooling on the properties of martensite. Details are given of a magnetic test for determining the transformation temperature.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Effect of Grain Size on Creep Strength. (Weaver, Steel, 24/2/41, pp. 80-85 and 92.) (89/48 Great Britain.)

The author states that the creep strength of a steel is correlated to the grain size. Special creep tests were devised to determine the optimum grain size when the creep temperature is above the "lowest temperature of recrystallisation" and also to determine the optimum grain size for differently alloyed steels at the same creep temperature. Other tests show variation in optimum grain size in the same steel at different creep temperatures. These data are united to produce a creep-strength-temperature-grain-size characteristic for carbon-molybdenum steel.

(Abstracts supplied by Research Department, Metropolitan-Vickers.)

Technical Developments on Metal Finishing during 1940. (Hall, Hogaboom, Metal Finishing, Jan., 1941, pp. 2-7, 10.) (89/49 U.S.A.)

Summaries of papers on metal finishing published during the year 1940 are presented in a form designed for ease of reference. The abstracts are classified in sections according to the purpose and type of the finish and contain details of many U.S. patents on electroplating.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Surface Treatment of Magnesium Alloy. (Schmidt and Others, Foundry Trade Journal, 13/3/41, pp. 175-7.) (89/50 Great Britain.)

This paper discusses the various methods of protecting magnesium alloys against corrosion by the atmosphere, salt water or other corrosive environments. It is stated that numerous tests and industrial uses of magnesium have proved that this metal is remarkably resistant to arduous atmospheric corrosion conditions. Details of some nine different processes for protective chemical coatings are given.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Age Hardening of Al-Zn-Mg Wrought Alloys. (W. Bungardt and G. Schaitberger, L.F.F., Vol. 18, No. 1, 28/2/41, pp. 26-31.) (89/51 Germany.)

The object of the authors research was to obtain a high tensile wrought alloy of Al-Zn-Mg possessing good corrosive resistance after quenching in water from 450°C. and subsequent age hardening at room temperature. The most suitable alloy was found to have the following basic composition:—

Zn	... ...	4.5%
Mg	... ...	.3%
Mn	... ...	.3%
Fe and Si	...	.2%

In order to improve both the strength and corrosion resistance under conditions of surface/stress (DVL cold rolled strip method), the addition of vanadium (.1 per cent.) and copper (up to 1 per cent.) has proved beneficial. The general corrosion resistance of such alloys is however reduced if the copper content exceeds .1 per cent.

The Creep Strength of Laminated Synthetic Pressed Resins. (H. Perkuhn, L.F.F., Vol. 18, No. 1, 28/2/41, pp. 32-37.) (89/52 Germany.)

The resins used in these experiments were of the phenol formaldehyde type, the laminations consisting either of cellulose (paper) or cotton tissue which constituted between 50 and 90 per cent. of the weight of the finished product. The pressing was carried out at 145°C. at pressures varying between 60 and 600 kg./cm.^{2}. The test rods had an overall length of 170 mm., of which 60 mm. constituted the working sectors (diameter 10 mm.). All the measurements were carried out at 20°C. at a relative humidity of 70 per cent. The following strength characteristics were determined:—

(1) Ultimate tensile (rate of loading 800 kg./cm.^{2}/min.).

(2) Static strength, *i.e.*, maximum stress which can be supported for at least 30 days without fracture.

(3) Creep strength, *i.e.*, stress which will produce a rate of extension of 5×10^{-4} per cent. per hour during the 10-hour period between the 100th and 110th hour of loading. After unloading and resting for 24 hours, the permanent stretch of the material must not exceed 2 per cent.

The ultimate tensile of the various samples varied between 1,000 and 2,000 kg./cm.^{2} (approx. 6-12 tons/sq. in.). The static strength varies between 50 per cent. and 75 per cent. of the ultimate, whilst the creep strength (as defined above) is generally less than 28 per cent. of the ultimate.

Speaking generally, it appears that a resin content of not more than 40 per cent. will give the best strength qualities. No improvement in quality is noted by exceeding a compression pressure of about 250 kg./cm.^{2} (1.5 tons/sq. in.) during manufacture.

Single Sampling and Double Sampling Inspection Tables. (Bell System Tech. J., Jan., 1941, p. 1-61.) (89/54 U.S.A.)

Whether sampling may be employed to advantage in place of 100 per cent. inspection usually depends on the purpose for which inspection is made. The sampling tables provide definite procedures for conducting inspections that have certain immediate purposes which are described in some detail. Through their provision for instituting a " screening " inspection whenever quality falls below an acceptable level, it is claimed that the procedures have been found in practice to enforce a programme of controlling quality in process as the alternative to high inspection costs. The paper includes an appendix of 32 pages of tables.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

A Micro Hardness Testing Machine. (Hanemann, Engineers Digest, Feb., 1941, pp. 42-44.) (89/53 U.S.A.)

Hardness testing by Brinell, Rockwell and Vickers methods affect a large number of crystals and hence the distribution, magnitude and quantity of the

crystals influence the result. Previous microscopic hardness measuring tests have been limited to scratch and abrasive methods which, however, measure rather the resistance to wear than the plastic deformation. This new micro hardness testing device has the indentor unified with the lens and is claimed to be very simple to handle. The surface of the sample is brought into focus and the sample so arranged that the crystal to be tested comes in the correct position. The objective is then lowered on to the specimen until the test load is reached. Measurement of the impression follows.

(Abstract supplied by Research Department, Metropolitan-Vickers.)

Experiment on Buckling Under Bending. (J. Casseus, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 306-13.) (89/55 Germany.)

The author gives expressions for the buckling load of a strut loaded eccentrically at both ends, the investigation being extended into the non-elastic region. The results are presented in three different ways, two of which are independent of the material of the strut, at any rate in the elastic region. The third method of presentation depends on the material and is mainly utilised for the easier comparison with experimental results.

A comparison of the buckling load of an open section loaded eccentrically (bending failure) with that obtained under conditions of central loading with no restriction against torsion shows that in the case of slender struts the former method of loading gives the higher critical value.

Some Notes on the Endurance and Fatigue Strength of Materials. (F. Bollenrath, L.F.F., Vol. 17, No. 10, 26/10/40, pp. 320-328.) (89/56 Germany.)

Laboratory tests on fatigue or endurance limits are often carried out under conditions which do not represent those occurring in practice. Broadly speaking, we have to differentiate between two kinds of practical loading:—

1. The structural element may be subjected throughout its life to a large number of periodic load cycles operating between definite limits.
2. The element is subjected to widely varying loads, the number of peak loads over a period of time being limited.

In the first case fatigue test of the usual kind over a series of constant stress limits (Wohler curves) should provide the necessary information, provided due attention is given to the order, type and frequency of the limits. In the second case, it is necessary to express the loading on a statistical basis with special reference to the possible effect of rest periods. Such a method of treatment applies principally to aircraft structures, but occurs also in certain forms of crankshaft and propeller loads.

In conclusion, the author calls attention to some factors other than the applied load which may affect the fatigue strength (surface pressing, method of clamping, fretting corrosion, etc.).

There appears to be no doubt that a further important saving in the weight of aircraft structure should be possible without reduction in safety if care is taken that the laboratory tests correspond more closely to the working conditions.

On the Space Attenuation of Impact Sounds in a Brick Building. (A. E. Knowler, Phil. Mag., Vol. 31, No. 206, March, 1941, pp. 240-6.) (89/57 Great Britain.)

A study of impact noises on concrete floors, as heard in the different rooms of a brick building, leads to the following conclusions:—

(1) The relation between the equivalent loudness heard in a room from the source of the impact noise is roughly linear.

(2) The space rate of attenuation of the loudness of dull blows is substantially more than that of sharp ones, the mean values for a concrete floor or uninterrupted brickwork being about 0.3 phon per ft. for the type of sharp blows used and about 0.5 phon per ft. for the dull blows.

(3) For the same type of blow, the space rate of attenuation down a longitudinal wall interrupted by windows may be 50 per cent. greater than that down an equally heavy unbroken transverse wall.

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING FEBRUARY, 1941.

THEORY AND PRACTICE OF WARFARE.

ITEM NO.		TITLE AND JOURNAL.
74/1	U.S.A. ...	*Chemical Warfare since* 1918. (A. L. Kibler, Ind. and Eng. Chem. (News Ed.), Vol. 18, No. 24, 25/12/40, pp. 1,122-25.)
74/2	Great Britain	*High Flying Military Aircraft.* (W. O. Manning, Flight, Vol. 39, No. 1,673, 16/1/41, pp. g-50.)
74/3	Germany ...	*Ju.* 88 *Dive Bomber (Photograph).* Flyning, No. 18, Sept., 1940, p. 4.)
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74/5	Great Britain	*Consolidated Model* 32 *(Liberator) Photograph.* (Aeroplane, Vol. 60, No. 1,547, 17/1/41, p. 63.)
74/6	Italy ...	*Macchi C.* 200 *Single-Seat Fighter.* (Aeroplane, Vol. 60, No. 1,547, 17/1/41, p. 74.)
74/7	U.S.A. ...	*Consolidated Model* 29 *Flying Boat, Photograph.* (Aeroplane, Vol. 60, No. 1,547, 17/1/41, p. 67.)
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74/10	Italy ...	*Italian S.M.* 82 *Canguru Bomber transporting Fiat C.R.* 42 *Single-Seat Fighter.* (Aeroplane, Vol. 59, No. 1,549, 31/1/41, pp. 142-4.)
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74/12	Germany ...	*Focke-Wulf F.W.* 187 *Two-Engine Fighter (Photographs).* (Aeroplane, Vol. 59, No. 1,549, 31/1/41, p. 146.)
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74/21	Germany ...	*Air Force Targets in Germany, No. XVI. The City and Port of Mannheim.* (Engineer, Vol. 171, No. 4,440, 14/2/41, pp. 110-1.)
74/22	U.S.A. ...	*Martin B-26 Medium Bomber (Photograph).* (American Aviation, Vol. 4, No. 14, 15/12/40, p. 6.)
74/23	Sweden ...	*Swedish Self-Sufficiency Hopes (Expansion of Aircraft Industry and Air Force.* (Inter. Avia., No. 739, 12/12/40, pp. 1-2.)
74/24	U.S.A. ...	*Vought-Sikorsky XF 4 U-1 Single Engine Fighter.* (Inter. Avia., No. 739, 12/12/40, pp. 7-8.)
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74/28	U.S.A. ...	*North American NA-68 Single Seat Fighter.* (Inter. Avia., No. 738, 4/12/40, p. 9.)
74/29	U.S.A. ...	*U.S.A. Aircraft Production. Review of Progress in Defence Programme and with Aircraft Orders for Britain.* (Inter. Avia., No. 738, 4/12/40, pp. 10-13.)
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74/143	Great Britain	*The Improvement of Mixed Cresols for Inhibitor Purposes: the Use of Mesitol as a Gum Inhibitor.* (T. Kennedy, J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, pp. 15-18.)
74/144	Great Britain	*The Effect of Alkyl Substitution on the Efficiency of Phenols as Inhibitors of Gum Formation in Petroleum Products.* (T. Kennedy, J. Inst. Petrol., Vol. 207, Jan., 1941, pp. 19-29.)
74/145	U.S.A. ...	*Effect of Surface on Cool Flames in the Oxidation of Propane.* (R. A. Day and R. W. Pease, J. Amer. Chem. Soc., Vol. 62, 1940, pp. 2,234-7.) (J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 21A.)
74/146	U.S.A. ...	*Study of the Monolayers of Some Esters and Chlorinated Derivatives Possibly Useful as Lubricating Addition Agents.* (G. L. Clark and J. V. Robinson, J. Amer. Chem. Soc., Vol. 62, 1940, pp. 1,948-51.) (J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 25A.) (Abstract available.)
74/147	U.S.A. ...	*U.S.A. Aviation Fuel Statistics.* (Inter. Avia., No. 738, 4/12/40, pp. 13-14.)

INSTRUMENTS.

74/148	Great Britain	*Modern Radiographs.* (Woods, Iron Age, 5/12/40, pp. 35-9.) (Met. Vick. Tech. News Bull., No. 744, 10/1/41, p. 5.)
74/149	Great Britain	*Electrical Transmission of Flow and Level Records.* (Linford, B.E.A.M.A. J., Dec., 1940, pp. 97-101.) (Met. Vick. Tech. News Bull., No. 745, 17/1/41, p. 4.) (Abstract available.)
74/150	Great Britain	*Radio Frequency Measurements (Review of Book) (Monographs on Electrical Engineering, Vol X—London, Chapman and Hall 21/-).* (L. Hartshoen, Engineering, Vol. 151, No. 3,915, 24/1/41, p. 63.)
74/151	U.S.A. ...	*Flight Test Data Mechanically Recorded (Planetest Magnograph).* (J. B. Darragh, Aero Digest, Vol. 37, No. 3, Sept., 1940, pp. 96, 99, 180.)

ITEM NO. TITLE AND JOURNAL.

74/152 Great Britain *Measurements at Radio Frequencies.* (Meahl, Scheldorf, Michel and Dickinson, Elec. Engng., Dec., 1940, pp. 654-9.) (Met. Vick. Tech. News Bull., No. 746, 24/1/41, p. 7.)

74/153 U.S.A. ... *A New Type of Power-Torque Meter.* (W. C. Hall, Engineer, Vol. 171, No. 4,440, 14/2/41, pp. 110-120.)

74/154 Great Britain *Viscosity and its Effects on the Accuracy of Positive Displacement Metering.* (J. W. Donnell, Proc. Petrol. Fluid Metering Conf., 11/4/40, pp. 13-21.) (J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 17A.)

74/155 U.S.A. ... *Fundamental Principles of Volume Meters.* (E. E. Ambrosius, Proc. Petrol. Fluid Metering Conf., 11/4/40, pp. 22-6.) (J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 18A.)

74/156 U.S.A. ... *Some Fundamental Considerations in the Design and Application of Displacement Meters.* (E. W. Jacobson, Proc. Petrol. Fluid Metering Conf., 11/4/40, pp. 29-33.) (J. Inst. Petrol., Vol. 27, No. 207, Jan., 1941, p. 18A.)

74/157 U.S.A ... *Curtiss-Wright Built-in Engine Torque Indicator.* (Inter. Avia., No. 739, 12/12/40, p. 9.) (Abstract available.)

74/158 U.S.A. ... *Heller Magnograph Test Flight Recording Instrument.* (Inter. Avia., No. 739, 12/12/40, pp. 9-10.)

74/159 U.S.A. ... *An Instrument for Continuous Measurement of Piston Temperatures.* (A. F. Underwood and A. A. Catlin, J.S.A.E. (Transactions), Vol. 48, No. 1, Jan., 1941, pp. 20-27.) (Abstract available.)

MATERIALS.

74/160 Great Britain *The Surface Treatment of Magnesium Alloys (concluded).* (H. W. Schmidt, W. H. Gross and H. K. De Long, Metal Ind., Vol. 58, No. 2, 10/1/41, pp. 29-32.)

74/161 Great Britain *Micro-Hardness of Metals in Thin Layers (New Diamond Indenting Instrument for Measuring Indentation Hardness of Brittle Materials).* (Metallurgia, Vol. 23, No. 134, Dec., 1940, pp. 33-4.)

74/162 Great Britain *Porosity and Analogous Problems in Aluminium Castings.* (Metallurgia, Vol. 23, No. 134, Dec., 1940, p. 34.)

74/163 Great Britain *Some Developments in Alloy Steel Production.* (J. H. G. Monypenny, Metallurgia, Vol. 23, No. 134, Dec., 1940, pp. 37-9.)

74/164 Great Britain *Some Scientific Problems Connected with Powder Metallurgy.* (E. A. Bano, Metallurgia, Vol. 23, No. 134, Dec., 1940, pp. 51-2.)

74/165 Great Britain *Some New Ferrous and Non-Ferrous Alloys, Their Composition and Uses.* (Metallurgia, Vol. 23, No. 134, Dec., 1940, pp. 53-4.)

74/166 Great Britain *Oxy-Acetylene Welding of Stainless Steels.* (L. Sanderson, Metallurgia, Vol. 23, No. 134, Dec., 1940, pp. 55-6.)

74/167 U.S.A. ... *The Impact of a Mass Striking a Beam.* (E. H. Lea, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 120-138.) (Abstract available.)

ITEM NO.		TITLE AND JOURNAL.
74/168	U.S.A. ...	*Analysis of Clamped Rectangular Plates.* (D. Young, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 139-142.) (Abstract available.)
74/169	U.S.A. ...	*The Orthogonally Stiffened Plate under Uniform Lateral Load.* (H. A. Schade, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 143-146.) (Abstract available.)
74/170	U.S.A. ...	*Some Observations on the Theory of Contact Pressures.* (S. Way, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 147-157.) (Abstract available.)
74/171	U.S.A. ...	*Boundary Friction in Bearings at Low Loads.* (L. M. Tichvinsky and E. G. Fischer, J. App. Mech., Vol. 7, No. 4, Dec., 1940, pp. 171-174.)
74/172	U.S.A. ...	*A Photoelastic Study of Stresses in Rotating Disks.* (R. E. Newton; J. App. Mech., Vol. 7, No. 4, Dec., 1940, p. 174.)
74/173	Great Britain	*The Slow Butt-Welding Process.* (Elect. Eng., 3/1/41, p. 278.) (Met. Vick. Tech. News Bull., No. 744, 10/1/41, p. 4.)
74/174	U.S.A. ...	*On the Right- and Left-Handedness of Quartz and its Relation to Elastic and Other Properties.* (K. S. Van Dyke, Proc. I.R.E., Vol. 28, No. 9, Sept., 1940, pp. 399-406.) (Abstract available.)
74/175	Great Britain	*Strength of Spot Welds.* (Neuman and McCreery, Weld. Engr., Dec., 1940, pp. 28-31 and 42.) (Met. Vick. Tech. News Bull., No. 745, 17/1/41, p. 2.) (Abstract available.)
74/176	Great Britain	*Reports of Investigations on Selected Types of High Tensile Steels.* (Reeve, Trans. Inst. Welding, Oct., 1940, pp. 177-202.) (Met. Vick. Tech. News Bull., No. 745, 17/1/41, p. 6.) (Abstract available.)
74/177	Great Britain	*Selection and Welding of Low Alloy Structural Steels.* (Deaden and O'Neill, Trans. Inst. Welding, Oct., 1940, pp. 203-214.) (Met. Vick. Tech. News Bull., No. 745, 17/1/41, p. 6.) (Abstract available.)
74/178	Great Britain	*A Defect in Mild Steel Welds.* (Benson, Trans. Inst. Welding, Oct., 1940, pp. 215-218.) (Met. Vick. Tech. News Bull., No. 745, 17/1/41, p. 8.) (Abstract available.)
74/180	U.S.A. ..	*Surface Quality of an S.A.E. 3,140 Steel: A Study Based on Various Combinations of Speeds, Structures and Cutting Fluids.* (O. W. Boston and W. W. Gilbert, Mech. Eng., Vol. 62, No. 11, Nov., 1940, pp. 785-9.)
74/181	U.S.A. ...	*Molybdenum in Iron and Steel.* (T. H. Parker, Mech. Eng., Vol. 62, No. 11, Nov., 1940, pp. 793-9.)
74/182	U.S.A. ...	*Modern Machines for Improving Production.* (H. F. Schwedes, Aero Digest, Vol. 37, No. 3, Sept., 1940, pp. 56-9, 184.)
74/183	U.S.A. ...	*Aircraft Machine Tools at the Northrop Plant.* (R. R. Nolan, Aero Digest, Vol. 37, No. 3, Sept., 1940, pp. 84-6, 184.)
74/184	U.S.A. ...	*Anti-Friction Bearings of High Capacity.* (E. K. Brown, Aero Digest, Vol. 37, No. 3, Sept., 1940, pp. 88, 91-2, 95, 108.)

ITEM NO.		TITLE AND JOURNAL.
74/185	U.S.A. ...	*Fatigue Strength of Castings Improved by New Screw Thread System.* (H. Caminex, Aero Digest, Vol. 37, No. 4, Oct., 1940, pp. 102-6, 109.)
74/186	U.S.A. ...	*Production of Aircraft Plywood.* (R. B. Anderson, Aero Digest, Vol. 37, No. 4, Oct., 1940, pp. 137-8.)
74/187	U.S.A. ...	*Sheet Metal Forming at the Martin Aircraft Plant.* (H. Chase, Autom. Ind., Vol. 83, No. 12, 15/12/40, pp. 621-4, 635.)
74/188	U.S.A. ...	*Drawn Tubing Obviates many Welds in Fuselage.* (H. L. Brownback, Autom. Ind., Vol. 83, No. 12, 15/12/40, pp. 625-8.)
74/189	U.S.A. ...	*New Electrode for Aircraft Welding* ("*Planeweld*"). (Autom. Ind., Vol. 83, No. 12, 15/12/40, pp. 632-3.)
74/190	U.S.A. ...	*Bearing Loads, Due to Universal Joint Action.* (A. Y. Dodge, Autom. Ind., Vol. 83, No. 12, 15/12/40, pp. 636-9, 654.)
74/191	U.S.A. ...	*Symposium on Industrial Application of Plastics, including Aircraft Construction.* (Autom. Ind., Vol. 83, No. 12, 15/12/40, pp. 644-5.)
74/192	Great Britain	*The Manufacture and Use of Cemented Carbides.* (H. Burden, Engineering, Vol. 151, No. 3,916, 31/1/41, pp. 86-7.)
74/193	Great Britain	*Pyramidal Diamond Point for Hardness Testing.* (Engineering, Vol. 151, No. 3,916, 31/1/41, pp. 87-8.)
74/194	Germany ...	*Materials with Special Temperature Dependence of the Elasticity Moduli.* (H. Fahlenbrach and H. H. Meyer, Z. Techn. Physik., Vol. 21, No. 2, 1940, pp. 40-4.) (Sci. Absts, "A," Vol. 43, No. 512, 25/8/40, p. 592.)
74/195	Great Britain	*Riveting of Light Alloys.* (Light Metals, Vol. 4, No. 37, Feb., 1941, pp. 23-5.)
74/196	Great Britain	*Fluxes for Magnesium Melting.* (Light Metals, Vol. 4, No. 37, Feb., 1941, pp. 25-6.)
74/197	Great Britain	*Age-Hardening Magnesium Alloys (contd.).* (W. F. Chubb, Light Metals, Vol. 4, No. 37, Feb., 1941, pp. 27-9.)
74/198	Great Britain	*Fluxes for the Welding of Aluminium.* (Light Metals, Vol. 4, No. 37, Feb., 1941, pp. 36-8.)
74/199	Great Britain	*Electro-Chemical Surface Treatment of Aluminium—and Magnesium—Base Alloys with Fluorine Compounds.* (Light Metals, Vol. 4, No. 37, Feb., 1941, pp. 39-40.)
74/200	Great Britain	*Iron-Plating Specimens for Microscopical Examination.* (Jenkinson, Iron and Coal Trades Review, 25/10/40, pp. 409-11.) (Met. Vick. Tech. News Bull., No. 735, 1/11/40, p. 7.)
74/201	Great Britain	*The Examination of Metals by Ultrasonics.* (Behr, Metallurgia, Nov., 1940, pp. 7-11.) (Met. Vick. Tech. News Bull., No. 738, 22/11/40, p. 8.)
74/202	Great Britain	*Production of Zinc Coatings.* (Bray and Morral, Metal Industry, 17/1/41, pp. 45-8.) (Met. Vick. Tech. News Bull., No. 746, 24/1/41, p. 7.)
74/203	Great Britain	*Brazing with Salt Bath Furnaces.* (Bellis, Metal Industry, 17/1/41, pp. 52-3.) (Met. Vick. Tech. News Bull., No. 746, 24/1/41, p. 8.)
74/204	Great Britain	*Cold Forming of High Strength Aluminium Alloy Sheet.* (Light Metals, Vol. 3, No. 34, Nov., 1940, pp. 267-9.)

ITEM NO.		TITLE AND JOURNAL.
74/205	Great Britain	*A System of Routine Radiology for Inspection of Light Alloy Castings for Aircraft.* (E. A. Allen and D. Haley, Light Metals, Vol. 3, No. 34, Nov., 1940, pp. 280-1.)
74/206	Great Britain	*Age-Hardening Magnesium Alloys.* (W. F. Chubb, Light Metals, Vol. 3, No. 34, Nov., 1940, pp. 284-6.)
74/207	Great Britain	*The Application of Ferrous and Non-Ferrous Wear Resisting Alloys (Hard Facing).* (Autom. Eng., Vol. 31, No. 406, Jan., 1941, pp. 13-16.)
74/208	Great Britain	*The Spot Welding of Light Alloys.* (G. H. Field and H. Sutton, Airc. Eng., Vol. 13, No. 143, Jan., 1941, pp. 17-26.)
74/209	Germany ...	*Design of Jigs for Metal Aeroplanes.* (F. Griebsch, Luftwissen, Vol. 5, No. 2, Feb., 1938, pp. 41-5.) (Airc. Eng., Vol. 13, No. 143, Jan., 1941, pp. 27-30.)
74/210	U.S.A. ...	*Magnesium Alloys for Aircraft Parts. A Summary of Current American Practice (Paper to S.A.E.).* (L. B. Grant, Metal. Ind., Vol. 58, No. 6, 7/2/41, pp. 149-51.)
74/211	Great Britain	*Hot Tensile Testing with Miniature Test Pieces.* (G. T. Harris, Engineering, Vol. 151, No. 3,917, 7/2/41, p. 101.)
74/212	Great Britain	*Combined Dimpling and Riveting Machine.* (Engineering, Vol. 151, No. 3,917, 7/2/41, p. 106.)
74/213	Great Britain	*Aluminium Casting Alloys for Internal Combustion Engines.* (Engineering, Vol. 151, No. 3,917, 7/2/41, p. 120.) (Abstract available.)
74/214	U.S.A. ...	*Fibre Glass Utilised for Wing Coverings.* (American Aviation, Vol. 4, No. 14, 15/12/40, p. 10.)
74/215	Germany ...	*Synthetic Brake Linings (Buna Rubber Bonded with Aluminium Fibres).* (Plastics, Vol. 5, No. 45, Feb., 1941, p. 21.)
74/216	Great Britain	*Synthetic Resin Adhesives and Cements.* (E. E. Halls, Plastics, Vol. 5, No. 45, Feb., 1941, pp. 31-3.)
74/217	Great Britain	*Some Theoretical Considerations on Box Beams.* (J. Drymael, J. Roy. Aer. Soc., Vol. 45, No. 361, Jan., 1941, pp. 5-28.)
74/218	U.S.A. ...	*Mechanism of Friction between Metals.* (W. L. Finlay, Sci. Am., Vol. 164, No. 2, Feb., 1941, pp. 78-81.)
74/219	U.S.A. ...	*Isolumen Plastic Sheet in Windows Resists Bomb Blast.* (Sci. Am., Vol. 164, No. 2, Feb., 1941, p. 100.)
74/220	Great Britain	*Stresses in Riveted Joints.* (J. D. W. Ball, Engineer, Vol. 171, No. 4,439, 7/2/41, pp. 100-101.)
74/221	Great Britain	*The Bent Strut with Variable Cross-Section.* (J. Drymael, J. Roy. Aer. Soc., Vol. 45, No. 362, Feb., 1941, pp. 51-66.)
74/222	Italy ...	*Calculation of Stresses in Thin-Walled Cylinders. Part III. The Method Applied to the Rectangular Shell Reinforced by Stringers.* (P. Cicala, L'Aerotecnica, Vol. 20, No. 10, Oct., 1940, pp. 735-46.)
74/223	U.S.A. ...	*Proposed S.A.E. Recommended Practice for Rating Magnaflux Indications.* (J.S.A.E., Vol. 48, No. 1, Jan., 1941, pp. 18-19.)
74/224	U.S.A. ...	*Wear-Resistant Coatings of Diesel Cylinder Liners.* (J. E. Jackson, J.S.A.E. (Transactions), Vol. 48, No. 1, Jan., 1941, pp. 28-32.)

ITEM NO. TITLE AND JOURNAL.

74/225 U.S.A. ... *The "Plug" Method for Obtaining the Compressive Elastic Properties of Thin-Walled Sections.* (H. W. Barlow, H. S. Stillwell and Ho-Shen Lu, J. Aeron. Sci., Vol. 8, No. 3, Jan., 1941, pp. 109-114.) (Abstract available.)

74/226 U.S.A. ... *Stable and Unstable Equilibrium of Plane Frameworks.* (N. J. Hoff, J. Aeron. Sci., Vol. 8, No. 3, Jan., 1941, pp. 115-9.)

METEOROLOGY AND PHYSIOLOGY.

74/227 Japan ... *A New Form of Condensation Hygrometer.* (T. Okada and M. Tamura, Proc. Imp. Acad., Tokyo, Vol. 16, April, 1940, pp. 141-3.) (Sci. Absts. "A," Vol. 43, No. 513, 25/9/40, p. 663.)

74/228 U.S.A. ... *Recent Fog Investigations.* (S. Petterssen, J. Aeron. Sci., Vol. 8, No. 3, Jan., 1941, pp. 91-102.) (Abstract available.)

74/229 Great Britain *A Comparison between the Geostrophic Wind, the Surface Wind, and the Upper Winds Derived from Pilot Balloons at Valentia Observatory, Co. Kerry.* (L. H. G. Dines, M.O. Professional Note, No. 83, 1938.)

74/230 Great Britain *The Relation between the Blueness of the Sky and (a) The Polarity of the Air, (b) The Gradient Wind.* (J. H. Brazell, M.O. Professional Note, No. 85, 1938.)

MISCELLANEOUS.

74/231 U.S.A. ... *Convergence of Hardy Cross's Balancing Process.* (R. Oldenburger, J. App. Mech., Vol. 7, No. 4, Dec., 1941, pp. 166-170.) (Abstract available.)

74/232 U.S.A. ... *Design Trends of American Passenger Cars for the Year 1941.* (T. A. Bissell, Autom. Eng., Vol. 31, No. 406, Jan., 1941, pp. 17-23.)

74/233 U.S.A. ... *Industrial Research in 1940. Advances in the U.S.A. and other Countries.* (W. A. Hamor, Ind. and Eng. Chem. (News Ed.), Vol. 19, No. 1, 10/1/41, pp. 1-16.)

SOUND, LIGHT AND HEAT.

74/234 Germany ... *The Similarity Law in Heat Theory.* (E. F. M. van der Held, Z. Techn. Physik., Vol. 21, No. 4, 1940, pp. 79-85.) (Sci. Absts. "A," Vol. 43, No. 512, 25/8/40, p. 628.)

WIRELESS AND ELECTRICITY.

74/235 U.S.A. ... *Radio Interception and Interference.* (R. Chandler, Coast Artillery Journal, Vol. 83, No. 6, Nov.-Dec., 1940, pp. 548-9.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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(Prepared by R.T.P.)

No 90. MAY, 1941.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revenue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.

J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes.
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Veroffentlichungen aus dem Gebtete der Nachrichtenteegnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Technical Problems of Anti-Aircraft Artillery. (K. Becker, Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 8-13.) (90/1 Germany.)

The article is mainly of interest as illustrating equipment utilised by the German air force in 1938. (Stereoscopic range finder—4 m. base, compact sound detector; mobile searchlights of 60 cm. and 150 cm. aperture, fire control, gear, 8.8 cm. anti-aircraft gun.) The latter fires a 9 kg. projectile at a muzzle velocity of 820 m./sec. It is stated that accuracy falls off rapidly due to wear of barrel and special arrangements are made for a quick exchange of worn parts. A diagram showing distribution of splinters (so-called butterfly diagram) for the 8.8 cm. shell is given, as well as shell trajectories at 10° intervals of the angle of elevation. The same diagram also contains the loci of constant longitudinal dispersion (both along the trajectory and in a horizontal direction) and constant lateral dispersion. It appears that a target placed at an altitude of 3,000 m. and at a distance of 5,000 m. is reached at a muzzle elevation of 35°. Under these conditions, the 50 per cent. longitudinal dispersion along the trajectory amounts to 40 m. In addition to this ballistic dispersion, errors due to the fire control gear itself must be considered.

Canopy Unit for Protecting Vital Plant during Raids. (The Engineer, Vol. 171, No. 4,450, 25/4/41, p. 275.) (90/2 Great Britain.)

A special arrangement of bracing members reduces the floor space required to support the canopy, which is adjustable for angle. It is made up of two H-section 5 in. by 3 in. steel upright stanchions mounted on base plates and carrying a pivoted angle steel frame. The latter carries three $\frac{3}{4}$ in. " Durasteel " (composite steel and asbestos) panels, giving a total area of cover of about 45 square feet. The canopy is strong and resilient enough to carry a considerable debris load and gives some protection from H.E. splinters and more complete protection from blast, debris and incendiary bombs.

Aircraft Armour. (H. J. Alter, Army Ordnance, Vol. 21, No. 125, March-April, 1941, pp. 497-498.) (90/3 U.S.A.)

The use of protective armour has a marked effect on the morale of the aircraft crew. The plane may be subjected to different types of ammunition fire, depending on whether it emanates from ground troops, anti-aircraft batteries or hostile aircraft. Ground troops use calibre 0.30 or 0.50 ball, tracer or armour piercing ammunition. Anti-aircraft batteries fire 3 to 5 in. shells, whilst hostile aircraft may employ 0.30 or 0.50 ammunition or cannon firing 20 or 37 mm. explosive shells. The structure of a modern aeroplane is rarely damaged to any serious extent by small bore ammunition and in many cases has even survived direct hits from large shells.

Both shell splinters and small bore ammunition, however, may damage personnel and equipment, since the normal covering of the aeroplane gives practically no protection. Ground troops and A.A. fire usually strike from below. Aircraft attacks are generally from the rear (15° below to 45° above the horizontal), but multi-seat fighters may attack from the lower forward hemisphere. The thickness of armour plate required will depend on the calibre and angle of impact of the bullet as well as on the " tumbling effect " of structural parts or equipment in the path of the bullet (*e.g.*, nose wheel helps to protect pilot and main landing wheels protect oil and fuel tanks against fire from below, auxiliary equipment in the cabin may help to deflect lateral bullets, etc.).

Homogeneous armour plate is generally preferred to the hard faced type since it can be formed into contours and is easier to manufacture. Moreover, experience has shown that the dispersion of the shots in aerial combat is such that impacts on the plate are nearly always more than 8 in. apart. Homogeneous plates $\frac{1}{2}$ in. thick will stop a 0.5 calibre armour-piercing bullet at 100 yards (20° impact). Three inches of bullet proof glass will do the same. In the former case, the bullet is shattered without appreciable cracking of the plate. In the case of the glass, however, the bullet is imbedded and visibility destroyed over a radius of 6 to 10 in. Flexible mounting of the armour plate is of no benefit for normal and dangerous at oblique angles of impact, since in the latter case the plate subjects the fastening bolts to excessive shear. Composition plates offer possibilities of saving weight, but are bulky and difficult to instal. Special shapes reducing penetration by means of blisters, pyramids or curved surfaces are feasible.

Armour plating should be installed so that it is accessible for replacement or repair. In order to save weight, it must be situated as closely as possible to the part needing protection. A critical comparison must be made between thin plates at oblique angles and thicker plates for more normal angles of impact. In any case, the tumbling action of the aircraft structure itself must be utilised to the full.

At the present time, the preponderance of attacks in the air will be from the rear at almost normal angles. The heaviest armour will be used to protect the pilot's head and back. The seat also requires armouring for protection against ground fire. Bullet proof glass is generally thought sufficient protection from fire coming from the forward hemisphere.

Studies on the Subsonic Flow of a Compressible Fluid Past an Elliptic Cylinder. (S. Tomotika and Kō Tamada, Aeronautical Research Institute, Tokyo, Vol. 15, No. 201, November, 1940, pp. 481-551.) (90/4 Japan.)

In the present paper, the two-dimensional irrotational subsonic flow of a compressible fluid past an elliptic cylinder placed at an arbitrary inclination to the undisturbed stream has been re-investigated by Poggi's method with the object of studying the manner in which the value of the so-called critical Mach number for the elliptic cylinder varies with the angle of attack as well as with the thickness ratio of the ellipse. (The critical Mach number is the value at which the local speed of sound is first attained in the field of flow, and according to the results of recent experimental investigations, it has a close connection with the important phenomenon called the compressibility burble.)

Speaking generally, the effect of compressibility is to reduce M critical by about 10 per cent. One of the interesting results obtained is that when the angle of attack has any value between 0° and 90°, the curve of the critical Mach number plotted against the thickness ratio t has a maximum at a certain definite value of t.

The effect of compressibility on the moment exerted by the fluid pressure about the centre of the ellipse is very marked. If M_1 = moment with compression, M_2 = moment without compression. M_1/M_2 is of the order of 1.5 and 1.2 for Mach numbers of 1 and 0.6 respectively. Up to Mach number 0.4 the results are in agreement with the simple Prandtl-Glauert expression.

Asymptotic Solution of Southwell and Squire's Equations of Fluid Motion for Larger Reynolds Numbers. (J. H. Preston, Phil. Mag., Vol. 31, No. 208, May, 1941, pp. 413-24.) (90/5 Great Britain.)

The asymptotic solution of Southwell and Squire's equations has been obtained directly from their original integral equation. This is found to lead to the same results as a simplified boundary layer theory developed by Burgers and to give the same position for breakaway as the "outer solution" first approximation by an entirely different method developed by Kármán and Millikan for the solution of the boundary layer equations. The results are in qualitative agreement with experiment, thus bearing out the remark of Southwell and Squire—that their modification to Oseen's equation should give an indication of the changes of flow pattern with Reynolds number, differing but little from Oseen's approximation at low Reynolds numbers. The solutions have been applied to the calculation of skin friction of elliptic cylinders. In the limiting cases of the plate and circle the results agree with those already obtained by Piercy and Winny and by Burgers.

In the case of the general cylinder, Piercy, Whitehead, and the present author have recently obtained an approximate solution of the boundary layer equations by the same method,* but the first approximation differs from that given here, no breakaway of the flow occurring. It is suggested that, starting with the asymptotic solution discussed above, successive approximations might be more rapidly convergent than those in reference (1) and preferable to the more usual method of solution in series.

Contribution to the Aerodynamics of the Fuselage. (H. Milthopp, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 52-66.) (90/6 Germany.)

The contribution of the fuselage and engine nacelles towards the total aerodynamic forces on the aircraft are considered for a number of important conditions of flight, special consideration being given to the wing fuselage combination. By means of conformal transformation, a simple wing equivalent to this com-

* Piercy, Preston, and Whitehead. "On the Approximate Prediction of Skin Friction and Lift." Phil. Mag. (7), p. 791 (November, 1938).

bination can be obtained for which the lift distribution is determined. From this the relative proportion of the load carried by the wing and fuselage can be calculated. The distribution of the load along the fuselage and the corresponding shift in the neutral stability point are estimated approximately from simple impulse considerations. In the case of side slip, the displacement flow of the fuselage causes an additional anti-symmetrical lift distribution along the wing, which in its turn results in a rolling moment of considerable magnitude. In addition, the side slip of the fuselage produces a lateral wind at the vertical fin and rudder and leads to appreciable modifications in the directional stability and damping during yaw.

In this connection some reference is made to N.A.C.A. Tech. Note No. 730.

Results Obtained by Measurements of Wing Stresses in Flight. (H. W. Kaul and B. Filzek, Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 20-25.) (90/7 Germany.)

Wing stressing occurring during flight is expressed in terms of the acceleration of the aircraft at its centre of gravity, and is evaluated by counting the number of acceleration peaks lying within definite equal acceleration increments Δb, irrespective of whether or not the acceleration falls to 1 g. after each peak. Measured results are plotted as a distribution polygon of relative frequencies, *i.e.*, the fraction of the total number of measured peak values falling within one particular stress group is plotted against the stress, expressed as a fraction of the additional gust load. Statistical results of wing stress measurements during flight, previously published by the D.V.L. (H. Freise, Jahrb, Luftfahrtforsch., 1938, Vol. 1, pp. 289-93) are supplemented by selecting aircraft used for definite purposes (*e.g.*, transport, aerobatics) and carrying out measurements during flight over long periods, with the aircraft in normal practical operation. In the case of the new commercial aircraft tested—Ha 139B and FW 200 (Condor) —the load frequencies in the individual stress classes were found to be considerably lower than those obtained in previous measurements on older types of commercial aircraft. This fits in with experience from the North Atlantic flights (Ha 139B) that the total gustiness over the ocean is less than that over land, and with the prediction made for modern landplanes (Condor), namely, that the total gustiness encountered would be smaller owing to the ability of the aircraft to select the most undisturbed stratum.

Relative load frequencies obtained during aerobatic flight in the Bucker " Jungmeister " were approximately in accordance with the distribution of stress for aerobatic flight proposed in previous publications. The absolute total frequencies per flying hour were higher than in earlier measurements on account of the very short pauses between various aerobatic figures. The positive maximum load factors during aerobatics, and those obtained in gust stress measurements on the He 70, in certain cases exceed the safety load factors prescribed in the German strength specifications.

Spring Type Shock Absorbers. (Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 25-26.) (90/8 Germany.)

The following types are discussed and illustrated:—

1. Telescopic steel tube, kept apart by the insertion of individual circular springs, arranged inside one another, so that under compression the outer rings expand and slide over the inner set, which at the same time contract. The arrangement is characterised by a considerable amount of friction damping.
2. As above, except that spring element consists of a number of spiral springs placed in series. Damping obtained by means of a separate

friction element sliding on the internal wall of one of the tubes, or oil damping by means of throttling is provided.

3. As above, except that damping is produced by a separate piston fitted with non-return valve.

The circular spring type of shock absorber with inherent friction damping has the advantage of simplicity and requires practically no servicing and maintenance. The addition of oil damping complicates the design, but makes it possible to adjust the spring characteristics under practical conditions. In addition to the above type utilising mechanical springs, shock absorbers utilising both air and oil for this purpose are also in use. In these designs, small deflections (such as arising when rolling on the ground) are balanced by air pressure only. The main landing shock is absorbed by oil, damping being either by means of piston displacing oil or by throttling the air circuit.

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Acoustical Studies of the Flutter of an Airscrew. (J. Obata and others, Aeron. Res. Inst., Tokyo, Vol. 15, No. 202, Nov., 1940, pp. 555-90.) (90/14 Japan.)

The natural frequencies of a non-rotating airscrew blade can be determined in a variety of ways. The simplest method consists in clamping the blade to a firm support, striking it with a hammer and determining the resultant vibrations electrically. In an alternative method, the airscrew is mounted on the shaft of a D.C. motor, the armature of which is supplied with alternating current of various frequencies whilst the field is directly excited. The author used both methods on five three-bladed aluminium alloy airscrews of approximately 2.9 m. diameter and of similar form. The fundamental bending frequency for all the blades was of the order of 35 vibrations/sec. with a first order torsional of the order of 315 vibrations/sec.

From an analysis of the flutter sound of the rotating airscrew, it was concluded that the following three modes of blade vibration are mainly responsible for the phenomenon :—

(1) Third order bending, 115 vibration/sec.
(2) First order torsional, 315 vibration/sec.
(3) Second order torsional, 590 vibration/sec.

When driven by an electric motor, only modes (2) and (3) (torsional) were observed. The third order bending vibration, however, may occur in flight.

Longitudinal Stability and Airscrew Rotation. (Inter. Avia., No. 759, 9/4/41, p. 8.) (90/15 U.S.A.)

Tests carried out at the Guggenheim Aeronautics Laboratory of the California Institute of Technology with a " powered " model of the Curtiss-Wright twin-engined transport showed just the reverse of the results obtained by Seifert in Germany (Jahrbuch der Deutschen Luftfahrtforschung, 1938) which indicated an improvement in static longitudinal stability by the use of airscrews swinging up and out. The author shows that the effect of opposite-rotating airscrews on static longitudinal stability depends upon the lift coefficient and on the design of the aircraft itself. A determination of the value of the opposite sense of rotation is not possible before, among others, the following problems have been clarified: (1) The effect of nacelle location relative to the wing; (2) the effect of tail location relative to both wing and thrust line; (3) determination of the quantitative effect of rotational components of the slipstream; (4) complete survey into the slipstream velocities at tail positions, and effect of the slipstream in changing the downwash at the tail. The tests carried out so far have shown, nevertheless, that for stability the tail should either be completely in the slipstream or completely out of it.

The Influence of Fuselage, Engine Nacelles and Wing Flaps on the Breakaway of the Flow at the Wing. (G. Hartwing, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 40-46.) (M.A.P. Translation No. 1,203.) (90/16 Germany.)

The model experiments were carried out by the Focke Wulf Company in connection with development work of the Condor type of aircraft. The breakaway of the flow was studied by taking photographs of silk threads attached to the surface of the wing. Three tapered wing models of the same span (1.32 m.), thickness and chord distribution, but differing in plan form, were used, the wing profile belonging to the N.A.C.A. 22 series (Tech. Rept. No. 460). Range of incidence up to maximum lift was covered, at two angles of yaw (0° and 9°), the wind speed being 32 m./sec. throughout.

Wing models 1 and 2 were of the same triangular shape without twist or dihedral, and differed only in having either the leading or trailing edge straight (*i.e.*, perpendicular to the fuselage axis). Model 3 corresponds to the Condor arrangement, with symmetrical taper as well as twist and dihedral. All the three wing models tested by themselves showed insufficient lateral control at maximum lift conditions, due to breakaway of the flow at one of the wing tips. In each case the instability started at the rear edge, spreading outwards and forwards. There was not much to choose between any of the wing plans, but on the whole the wing with the straight trailing edge appears to be the most critical.

Matters were, however, completely changed when model 3 was fitted with fuselage and engine nacelles. The breakaway now starts at the wing root fillet and is confined to the central section of the wing span. The air flow at the wing tips remains sound over the whole experimental range, even with flaps and ailerons fully extended on the model.

The difference in behaviour is associated with changes in the cross flow at the wing, which flow apparently extends above the surface to a distance of the order of 30 per cent. of the wing chord.

Measurements with the Six-Component Balance on a Model of a Single Float Seaplane. (O. Pabst, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 47-51.) (90/17 Germany.)

The experiments had as their objects the determination of the aerodynamics load on the structure of a seaplane whilst still attached to the catapult on the ship's deck. Due to the motion of the ship, the plane may be subjected to considerable angles of roll (*i.e.*, 30°) whilst the relative wind may strike the structure at any lateral angle between 0° and 360°.

Experiments were accordingly carried out over this range of yaw and roll, but at a fixed angle of incidence of 5.5° (corresponding to the setting on the catapult). The model of a single float biplane with wing tip floats had a span of 1,235 mm. and a maximum length of 1,125 mm. The wind speeds utilised ranged from 17 to 32 m./sec. In order to cover the wide range of settings readily, the normal suspension system of the six component balance (Goettingen type) of the Focke Wulf laboratory was modified. As before, the model is held at three points, two of which are at the front on the same lateral axis whilst the rear point of attachment lies on the axis of symmetry of the wing. The wire suspension to one of the front points is in the form of a pyramid, ending in a triangular frame work attached to one of the lift balances. Forces in all three directions are transmitted. The other front point is held by only two wires attached to a cross bar suspended from a second lift balance, only horizontal (drag) and vertical (lift) force being measured. The rear suspension is by means of a single wire to a third lift balance, only vertical forces being transmitted. Horizontal (drag) force components at the two front suspension points are transmitted by means of ball bearing links to two drag balances respectively, whilst a third link attached to the pyramid frame enables its lateral

(cross wind) force to be measured. All the links are carried by the balance table so that a single rotation of the latter turns both the model and suspension without any additional adjustment being required. This is a great improvement on the original balance in which the adjustment for yaw was separate from the balance and required several observers for its manipulation. The experimental results are given graphically and cover normal, longitudinal and lateral force coefficients as well as rolling, pitching and yawing moment coefficients over the range 0°-360° of lateral wind, with rolling angle as parameter. The normal force coefficient with flaps extended is also given. Speaking generally, the results do not differ markedly from those obtained by Kohler over the same range (L.F.F., Vol. 14, 1937, p. 583) for a seaplane resting on the water.

The Influence of Mach Number on the Efficiency of Airscrew. (H. Wolff, Vol. 18, No. 2-3, 29/3/41, pp. 67-69.) (90/18 Germany.)

In a previous paper (L.F.F., Vol. 14, 1937, pp. 168-172) Weinig has shown that the effect of high tip speeds on the efficiency of airscrews can be represented by a correction factor η_u, which is a function of Mach number (for the blade tip) and average lift coefficient of the blade only. The following theoretical values were obtained by Weinig for various values of the lift function $\bar{c}_a$.

	η_u / Lift function $\bar{c}_a$		
M	.2	.8	1.2
0.5	—	0.99	0.98
0.7	0.99	0.97	0.95
1.0	0.96	0.89	0.79

In the above, the lift function is given by

$$\bar{c}_a = \frac{\pi k_s}{\frac{2}{3} z l_{m/D}}$$

where k_s = thrust coefficient $= \dfrac{S}{\rho/2\, u^2 F}$

and $l_{m/D}$ = mean chord/diameter of blade

$$= 4\int_0^1 \frac{1}{D}\left(\frac{r}{R}\right)^3 d\left(\frac{r}{R}\right)$$

z = number of blades.

In the present paper the author describes flight tests carried out on the Focke Wulf Condor, from which η_u is deduced by noting the apparent increase in drag of the aircraft with airscrew r.p.m., although v/u was maintained constant (v = flight speed, u = airscrew tip speed). The values obtained for η_u check up well with some N.A.C.A. full-scale tests (Tech. Rept. 639) and show an appreciably greater effect at high c_a and Mach numbers than Weinig's theoretical values. On the other hand, the flight tests show no compressibility effect at Mach numbers below about 0.65. Apart from the blade profiles being suited for high speed work (thin sections with maximum thickness at 40 per cent. chord and beyond) it appears that efficient operation at high Mach numbers require an almost constant pitch distribution between 0.7 R and the blade tip. The blade width of such airscrews must also be greater than is common practice to-day.

Fuel Vapour Lock (C.F.R. Report). (Inter. Avia., No. 744-5, 16/1/41, pp. 13-14.) (90/19 U.S.A.)

The formation of vapour lock in fuel systems depends, for a given fuel, on its vapour pressure, the external pressure on the fuel and the fuel temperature. In order to avoid an excessive formation of vapour (in some cases even the

boiling of fuel), such as can occur on high altitude flights after a take-off at high temperatures and with fuel of high vapour pressure, several solutions have been suggested. The use of fuels of lower vapour pressure would naturally result in an improvement but has the disadvantage that special fuel would be required to start the engines and the fire hazard would increase. Furthermore, the desire of lower vapour pressure is contrasted by the demand for fuels of increasingly high octane ratings. Another possibility consists in the increase of the fuel tank pressure, either by supercharging or suitably controlled tank ventilation.

The cooling of the fuel in the tanks is cited as another method to prevent trouble resulting from vapour lock formation; however, this would be accompanied by a considerable weight increase and would therefore be impracticable for smaller aeroplanes. All the suggestions mentioned above have grave disadvantages, so that efforts will probably be made also in the future to prevent vapour lock by the suitable installation of the fuel systems in the aircraft alone. (1) The fuel system must be so installed that vapour removal is easy and that there are no vapour traps. (2) The pressure drop through the system must be minimised by decreasing the flow resistence in fittings, elbows, tee outlets, etc. (3) Pressure losses due to interior or external accelerations acting on the fuel flow, must be avoided; it is recommended not to feed the fuel to the engines by means of suction pumps located near the power plant but to force it to the engines by means of pumps situated near the tanks. In order to facilitate the task of the manufacturers, the C.F.R. Committee has completed the standardisation of streamline tube fittings, elbows, etc., and will shortly extend its investigations also to lubricants.

Essolube HD—New Type of Engine Lubricant. (Ind. and Eng. Chem., News Ed., Vol. 19, No. 5, 10/3/41, p. 282.) (90/20 U.S.A.)

The Standard Oil Co. of New Jersey has announced a type of engine lubricant, Essolube HD, developed to overcome piston varnishing, ring sticking, and other major lubrication troubles which have limited output of many heavy duty, high speed Diesel and petrol engines.

This new lubricant marks the first time the petroleum industry has been able to offer highly detergent or washing properties incorporated in a highly stable, high viscosity index base oil. The new Essolube HD has a viscosity index of approximately 100—nearly twice that previously available in special detergent oils meeting the full range of known heavy duty engine requirements. The new lubricant, in addition to inherent natural resistence to oxidation and high temperature has an exceptionally high ability to wash out sludge deposits, protect bearings from corrosion, and prevent to a large extent deposits of varnish on pistons, valve stems, rings, and other engine parts. It also has a valuable rust preventive action.

Oxidation of Petroleum Lubricants. (L. L. Davis and others, Ind. and Eng. Chem., Ind. Ed., Vol. 33, No. 3, March, 1941, pp. 339-350.) (90/21 U.S.A.)

The oxidation of petroleum lubricants is an autocatalytic reaction, the initial phases of which have been investigated by an oxygen absorption test. Effects of crude source, refining, accelerators, and inhibitors may be thus studied.

Two types of inhibitors are distinguished—true anti-oxidants and precipitants. The latter only are effective against metallic accelerators. Oxidation products are proximately separable by solvents and absorption methods. Ultimate analyses of insolubles and oil-soluble resins, stepwise separated from used oil, show decreasing oxygen contents.

Practical engine tests must finally determine the choice of inhibitors. Such tests emphasise the advantages of certain sulphur-bearing derivatives over simple anti-oxidants.

Lubricating Oil Addition Agents. (O. M. Reiff, Ind. and Eng. Chem. Ind. Ed., Vol. 33, No. 3, March, 1941, pp. 351-357.) (90/22 U.S.A.)

New types of metal salt addition agents for lubricating oils have been developed from alkylated phenolic compounds. By the introduction of alkyl substituents derived from petroleum wax, multi-functional addition agents are formed which are capable of imparting combined properties such as four-point depressant action, improved viscosity index, and anti-oxidant value to lubricating oils. The effectiveness of the multi-functional addition agents is improved by the introduction of metal substituents, particularly in respect to anti-oxidant value. Attention is directed to the importance of the type of solubilising radical as well as the kind of metal substituent in the formation of metal salt addition agents having anti-oxidant value.

Spontaneous Ignition of Hydrocarbons. (C. W. Sortman and others, Ind. and Eng. Chem., Vol. 33, No. 3, March, 1941, pp. 357-360.) (90/23 U.S.A.)

Spontaneous ignition temperatures in air, and the corresponding time lags, have been determined for a variety of hydrocarbons at atmospheric pressure by the oil-drop or Moore method, using a steel crucible and different air flow rates and liquid drop sizes. Under some conditions of air and liquid feed the readily ignited hydrocarbons, such as cetane and heptane, show two separate temperature zones of non-ignition above the minimum ignition temperature, a behaviour heretofore unobserved; under other conditions one or both of these zones are eliminated. The conditions of air and liquid feed also have a marked effect on the ignition time lag, especially at low temperatures. Addition of tetraethyl lead completely inhibits ignition up to about 850-1,000°F. (454-538°C.).

Temperature and Latent Energy in Flame Gases. (W. T. David, The Engineer, Vol. 171, No. 4,450, 24/4/41, p. 268-270.) (90/24 Great Britain.)

Flame gases are not just hot normal gases. It has been shown that they contain a long-lived latent energy which probably resides as an excess of intra-molecular energy in a proportion of the tri-atomic molecules formed during combustion. The excess intra-molecular energy in these abnormal molecules appears to be of a type which cannot be handed over to the translational degrees of freedom during molecular collisions.

In virtue of the long-lived latent energy, the ideal flame gas temperature, calculated upon the basis of accurate specific heat and dissociation data, is not usually attained.

Owing to latent energy the ideally calculated pressures are not fully attained in closed vessel explosions, even after allowing for the heat loss which takes place during explosion.

The latent energy seems to disappear and the abnormal molecules to become normalised when the flame gases come into contact with surface. An experiment which seems to prove this is described. It may be that the effectiveness of flame gases in many industrial processes results from the unloading of latent energy upon surface.

Recent Developments in Internal Combustion Engines. (J. T. Davies, J. Royal Soc. Arts, Vol. 89, No. 4,581, Feb. 21, 1941, pp. 171-210.) (90/25 Great Britain.)

The author deals with his subject matter in three lectures, of which the first briefly enumerates present fields of application of I.C. engines (marine, stationary, rail and road transport and aircraft), the second deals with fuels and lubricants, and the third gives some account of supercharging and emergency fuels (gas and coal dust). Engines for marine and stationary work as well as rail and heavy road transport operate almost exclusively on oil fuels, whilst petrol still holds the field for aircraft and light road transport.

In dealing with developments the author naturally gives prominence to fields in which he is personally interested and in the present lectures considerable space is devoted to the rating of oil fuels in terms of ignition lag and to inertia scavenging of the Kadenacy type. The importance of improving the efficiency of supercharge and scavenge pumps is stressed, but no indication of development work on these important accessories is given.

It appears that two-stroke working, both for oil and petrol, will become more general in the future as the simplest method of improving power output for a given weight of mechanism. In the author's opinion, the abundance of high quality liquid fuel in this country has detrimentally affected our export market, in so far that British designs are generally not flexible enough. In conclusion, the author utters a plea for subsidised research and the placing of extensive Government contracts.

The Ageing (Precipitation Hardening) of Aluminium Alloys. (A. Von Zeerleder, Flugwehr and Technik, Vol. 2, No. 11-12, Dec., 1940, pp. 261-263.) (90/26 Switzerland.)

The age hardening of duralumin has been known for over thirty years. A scientific explanation of the process is only of relatively recent date. The phenomenon was discovered more or less accidentally by Wilm in 1909, although the ground had been prepared by systematic research. Wilm was investigating the possibility of utilising light alloys for cartridge cases and had prepared a large number of Al-Cu-Mg-Mn alloys of variable composition for this purpose. The metal sheets were prepared from the castings by cold rolling, which, in order to prevent cracking, had to be carried out in stages with interposed periods of annealing. Wilm investigated the effect of sudden quenching in water from various annealing temperatures and it so happened that a batch had been quenched prior to closing down the laboratory for the week-end. Fortunately a Brinell hardness determination was however made in order to obtain some idea of the success of the heat treatment. Fuller tests carried out after a " rest " period of forty-four hours showed a considerable improvement of the material and revealed the process of " ageing." According to modern views, the ageing is due to a gradual precipitation of very finely divided copper from the Cu-Al mixed crystals present at higher temperatures ($> 500°C.$) and " frozen " by the sudden quenching. These crystals are unstable at lower temperature and the tendency towards a new equilibrium exerts powerful forces on the space lattices which are reflected in improved strength characteristics.

If such " aged " material is reheated to a critical temperature of about 130°C., the molecular tensions are released, the copper comes out of solution in a coarse form and the alloy becomes soft.

Ordinary Al-Cu alloys show only slight " ageing " at room temperatures in the presence of Mg however, the effect is completed in about 96 hours, one half of the final improvement being reached in less than four hours. For certain purposes, *e.g.*, rivets, this rapid ageing is detrimental and such alloys will either have to be worked within a short time of heat treatment, or the ageing slowed down by storing at a lower temperature (ice box). Both these alternatives have their drawbacks and recently a new Ac-Cu-Mg alloy (Avonal NL) has been developed, rivets of which can be kept for periods up to ten hours before becoming too hard for use. It is possible to slow up the ageing process still further and obtain Al-Cu-Mg alloy which require prolonged annealing at 100-150°C. before the full strength is developed by precipitation hardening (Super Avional). Unfortunately such alloys are much more sensitive to corrosion than the normal product and require " cladding " or other suitable form of protection.

The corrosion difficulty can be overcome and the advantage of high ageing temperature retained by substituting silicon for copper in the alloy. The resultant

product is known as Anticorodal, and although not as strong as alloys of the Dural type, it can be stored indefinitely in the semi-hard condition. It is relatively easy to work, the finished product receiving its maximum strength after annealing to 150°C. for about four hours.

It must, however, not be forgotten that whilst the ageing process can thus be speeded up by annealing at elevated temperatures, leading to an improvement in the material, any prolonged exposure to temperatures in excess of about 130°C. leads to a coarse precipitation and a reduction in the final strength value.

Alloys showing the characteristics of age hardening are thus unsuitable for structural parts subjected to prolonged periods of elevated temperatures.

Displacements Determined by Airy's Stress Functions. (H. M. Westergaard, J. App. Mech., Vol. 8, No. 1, March, 1941, pp. 1-2.) (90/27 U.S.A.)

Airy's stress function defines a plane state of stress by simple formulæ. When the constants of elasticity are known the function will also define the strains, but the determination of the displacements is less direct. The solution described in this paper may be interpreted as a variant of Love's solution. Simple formulæ are obtained by the use of functions of a complex variable.

Influence Surfaces for Stresses in Slabs. (F. M. Baron, J. App. Mech., Vol. 8, No. 1, March, 1941, pp. 3-13.) (90/28 U.S.A.)

This investigation presents a formal analytical solution of some problems involving influence surfaces for stresses in slabs. It deals primarily with the determination of influence diagrams for stresses in homogeneous elastic slabs and is based upon the extension of Müller-Breslau's principle established in structural mechanics. The analysis is based upon the classical procedure of obtaining a solution of Lagrange's differential equation of the deflected middle surface of the slab satisfying at the same time all of the boundary conditions at the various edges.

The influence surface for a bending moment at a point on the fixed edge of an infinitely long rectangular slab, with a fixed edge transverse to two parallel simply supported edges, is defined by a function in finite form. Contour lines of the influence surfaces for the bending moments at the quarter points and at the mid-point of the fixed edge are given.

Influence functions are stated for the moments at the mid-point and at a point on the fixed edge of a circular slab with a fixed edge. Contour lines of the influence surfaces are given.

Each solution defining an influence surface for a stress at a given point of a homogeneous elastic slab may also be used to solve the related two-dimensional problem of stresses in a slice. A slab is converted into a slice when the loads applied transversely to the slab are replaced by forces that are parallel to the middle plane of the slice and produce no bending or transverse shears.

An Eddy Current Method of Flaw Detection in Non-Magnetic Metals. (R. Gunn, J. App. Mech., Vol. 8, No. 1, March, 1941, pp. 22-26.) (90/29 U.S.A.)

An equipment suitable for the location of surface or submerged flaws in non-magnetic metals is described. A predetermined pattern of electrical eddy currents is induced in a perfect test sample by alternating magnetic fields. Sensitive pick-up coils properly disposed in relation to the eddy currents measure only the departures of the eddy current pattern from the pattern in the perfect sample. The departures are indicated on a meter or may be recorded. Performance data are given for a universal type of search unit especially adapted for general surveys.

An Extension of the Photo-elastic Method of Stress Measurement to Plates in Transverse Bending. (J. N. Goodier, G. H. Lee, J. App. Mech., Vol. 8, No. 1, March, 1941, pp. 27-29.) (90/30 U.S.A.)

The well-known photo-elastic method for models in plane stress is extended to plates bent transversely by cementing together two similar plates with a thin layer of reflecting material between them. The light thus traverses twice one half of the full plate thickness, in which the stress in the simplest case is all of one sign, so that a net optical effect is obtained. Measurements on a strip of celluloid in pure bending, and with circular holes, yield results in conformity with theory; but a Bakelite model with circular holes showed discrepancies indicating that the cement bond between the Bakelite and the reflecting layer (aluminium foil) was not adequate. Results of measurements on semi-circular notches in a strip under pure bending are also given. The difficulties and potentialities of the method are discussed.

Rubbers Natural and Synthetic. (J. W. Schade, J. Aeron. Sci., Vol. 8, No. 5, March, 1941, pp. 177-182.) (90/33 U.S.A.)

The meaning of the word rubber has changed since the advent of synthetic materials similar to the natural product. It is now used to designate a class of flexible elastic materials rather than a particular hydrocarbon product of natural origin. The synthetic rubbers are classified into five types. The mechanical properties of all types are determined not by the kind of chemical elements composing them, but rather by the arrangement of these elements, the size of the molecules and by structures produced by vulcanisation. All rubbers are modified by addition of other materials to fit them for a variety of uses. Differences in chemical composition and in the properties of natural and synthetic rubbers are shown in tabular form.

Mechanically, natural rubber is not surpassed by any synthetic rubber. However, in resistance to swelling by organic liquids, such as petrol and oils, and to deterioration by sunlight or oxidising agents, synthetic rubbers have been found superior. These characteristics directed commercial applications to those fields where these properties are particularly needed.

Aircraft Plywood and Adhesives. (T. D. Perry, J. Aero. Sci., Vol. 8, No. 5, March, 1941, pp. 204-216.) (90/34 U.S.A.)

At the period of the 1914 War, either casein (made from the curds of soured milk) or albumen (a dried blood product coagulated under heat) were considered the most durable adhesives for aircraft construction. Neither of these products resisted moulds or fungi. Casein is not very resistant to water. Albumen is better in this respect, but deteriorates seriously with age. After 1930, adhesives made of synthetic resins revolutionised the plywood industry (phenol and urea form aldehydes). These new compounds are characterised by good water resistance, they are not attacked by mould and fungi and are much less damaging to edge tools than the caseins (adhesives). Recently so-called " plastic " aircraft has received much publicity. These planes are made of moulded plywood, the only novel feature being the method of applying the pressure as well as the unusually large size of the moulded unit. The fundamental principle involved is that of using an inflated or deflated rubber bag as one of the halves of a pair of moulding dies. Typical examples of such dies are illustrated. The conventional method of manufacturing aircraft plywood with synthetic resin adhesives has been the use of the steam heated plater in a hydraulic press. Recently, for thick sections, heating by means of high frequency electrostatic fields has been successfully carried out.

The author gives some details of wood and plywood construction (spars, ribs, gussets, skin covering, high density reinforced plates, propellers and bending).

Useful tables of the weight, tensile, and bearing strength of a number of representative plywoods are given (including high density woods).

A bibliography of fifty-eight items concludes the paper.

Quenching Stresses in Aluminium Alloys. (Zeerlander, J. Inst. Met., March, 1941, pp. 87-99.) (90/35 Great Britain.)

This paper deals with the internal stresses in Avional D alloy set up by quenching, and of the possibility of eliminating them by subsequent cold work. The method used for determining the stresses consisted in measuring the dimensional changes of the stock during step-by-step removal of the outer layers. The variables studied are: Time between solution treatment and quenching, temperature and nature of the quenching medium, temperature of ageing, and cold working before or after ageing. It is shown that the stresses are materially reduced and may even be reversed by cold working before or after ageing. Illustrated by one photograph and 12 graphs.

(Abstract supplied by Met. Vick. Research Dept.)

Theory of the Plastic Properties of Solids. (Sictz and Read, J. App. Phys., Feb., pp. 100-118, and March, 170-186, 1941.) (90/36 Great Britain.)

From the viewpoint of direct experimental observation, the plastic properties of solids may be classified into five categories, namely: (*a*) Slip, (*b*) creep, (*c*) twinning, (*d*) rupture, and (*e*) fatigue. The phenomenon of slip is dealt with at considerable length and the various physical aspects of hardening are briefly mentioned.

Illustrated by one photograph, 13 diagrams and 25 graphs.

(Abstract supplied by Met. Vick. Research Dept.)

Protective Finishes for Aluminium Aircraft Surfaces. (Cordy, Steel, 10/3/41, pp. 56, 72 and 102.) (90/37 Great Britain.)

Corrosion may easily reduce the endurance limit of aluminium alloy by as much as 67 per cent. and hence the retention of maximum physical properties which is so necessary in aircraft construction, necessitates adequate attention to corrosion prevention. In this article the author details the factors involved and various means of corrosion prevention, and describes the practice employed by the Curtiss-Wright Corp. of U.S.A., which involves the production of a tough protective film. (Illustrated by three photographs.)

(Abstract supplied by Met. Vick. Research Dept.)

Induction Hysteresis. (Holslag. Weld. Ind., April, 1941, pp. 70-72.) (90/39 Great Britain.)

Details are given in this paper of methods of application of induction hysteresis to preheating, welding and normalising. It is claimed that this relatively new process is a definite proved advance in welding and is particularly applicable to power plant high-pressure piping, boilers, valves and turbine connections.

(Abstract supplied by Met. Vick. Research Dept.)

Relaxation of Metals at High Temperatures (Trumpler, J. App. Phys., March, 1941, p. 248-253.) (90/40 Great Britain.)

The term " relaxation " is used when an initially pure elastic strain is gradually transformed into a permanent strain while the length of the bar remains unchanged. Details are given of an apparatus designed and built primarily to duplicate such conditions in connection with the study of bolt materials for steam turbines. It is claimed that the unusual accuracy and the exceptionally good test results obtained from the automatic relaxation machine during more

than two years of operation indicate that the type of test may well become a standard creep test. (Illustrated by one diagram, one photograph and eight graphs.)

(Abstract supplied by Met. Vick. Research Dept.)

Investigation on the Mechanism of the Cementation of Metals. (M. Goto and others, Aeron. Res. Inst., Tokyo, Vol. 15, No. 200, Oct., 1940, pp. 431-476.) (90/41 Japan.)

Cementation is a method of coating the surface of one metallic material with another metal, by which the material to be coated is surrounded with the coating material in powdered form, and the vapour of the coating metal is diffused into the other material. Within this definition come the carburising process, the nitriding process, etc., but it is a question whether cementation can be effected perfectly when the vapour pressure of the material to be coated is far greater than that of the coating metal, as in the case of applying molybdenum to nickel.

In the present experiments, round bars of nickel surrounded by molybdenum powder were cemented under various conditions of heating temperature, heating period, heat treatment after cementation diffusion agent, etc., but adequate cementation could not be effected. The test results were studied by means of microscopic examination and X-ray analysis in order to obtain some idea of the mechanism of cementation, and as a result a two-stage heating process was developed by means of which it is possible to effect adequate cementation. The concentration of the molybdenum of the cementation coating was determined by X-ray analysis, and its density was examined by means of hydrochloric acid corrosion.

Tests were also made with some nickel alloys, and the effects of the alloying elements were partially clarified.

Magnesium in Aircraft. (Inter. Avia., No. 759, 9/4/41, pp. 8-9.) (90/42 U.S.A.)

In order to improve the aerodynamic refinement of an aeroplane, very smooth surfaces are required, and great demands are placed on the buckling strength of the aircraft skin, for example in dives. By means of flush riveting, spot welding and other methods, satisfactorily smooth surfaces can be obtained; however, the strength of thin gauge skins is not sufficient to maintain the surface smoothness also under great loads, as a result of which increasingly heavy skins will be required in monocoque construction. Furthermore, the loads placed on the skin by the local formation of compressibility shock, resulting from the velocity of sound being exceeded locally, can grow to such an extent that heavier sheet than heretofore must be employed. According to the Dow Chemical Co. (Spring Session of the Society of Automotive Engineers) magnesium alloys are quite suitable for use as skin material in view of their low specific gravity.

Importance of Suitable Direction of Deflection of Flight Control Instruments. (E. Everling, Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 26-27.) (90-43 Germany.)

The direction of deflection of a flight control instrument should be such that its reading can be converted mechanically and unconsciously by the pilot into the correct control movement. This is particularly important when he has to change from normal to blind flight, since during a right hand turn, for example, a visible object on the ground moves apparently to the left whilst the pointer on the turn indicator moves to the right. Systemmatic tests have, therefore, been made to discover how men of various degrees of technical suitability and training operated the rudder and aileron controls on seeing a deflection of the turn indicator or compass. The instruments were arranged so that they could also deflect in the reverse direction. The test persons comprise ages between 12 and 62 and included pilots, women pilots, students, and apprentices with and without technical

knowledge. The reaction time and time taken to adjust the controls for steering by the compass or turn indicator were recorded in each case with the instrument pointers deflecting in both normal and reverse directions. The results showed that a pilot would respond to the compass, and probably also to the turn indicator, with quicker and more accurate control movements if these instruments were made to deflect in the reverse direction. This could be done by a simple technical modification in the case of the turn indicator and in the case of the compass by allowing only the rear part of the rose to be visible.

An Instrument for Measuring Short Intervals of Time. (E. A. Walker, J. of Franklin Inst., Vol. 231, No. 4, April, 1941, pp. 373-379.) (90/44 U.S.A.)

This paper describes a meter for measuring short intervals of time. Full-scale deflections of 0.001, 0.1 and 1.0 second can be obtained by the use of a selector switch. This meter will indicate the length of time a contact remains closed, or the interval of time between the closing of one circuit and the opening of another. The device has a linear scale for any chosen range. It measures time by the charge which flows to a condenser during the interval. The charge is found by reading the potential difference on the condenser with a sensitive vacuum tube voltmeter. The limit of accuracy as determined by test appears to be the accuracy with which the ammeter in the plate circuit can be read. The theory of the circuit and its advantage over other devices for the same purpose are discussed.

The Daytime Photo-electric Measurement of Cloud Heights. (M. K. Laufer and L. W. Foskett, J. Aeron. Sci., Vol. 8, No. 5, March, 1941, pp. 183-187.) (90/46 U.S.A.)

A photo-electric detector is used in conjunction with a modulated beam of light for the measurement by triangulation of the height of clouds during the daytime. An A.C. operated mercury arc lamp is used to obtain the modulated beam. An electronic " synchronous switch " is used to eliminate the effect of the varying background brightness of the clouds. The shot noise of the photo-tube resulting from the relatively high brightness of the clouds during the daytime limits the detection. Dark overcast clouds at an elevation of 9,000 feet have been detected.

Electrical Apparatus for Testing Reaction—Time and Hand and Eye Co-ordination. (R. C. Woods and A. S. McDonald, J. Inst. Elect. Eng., Vol. 88, Part 1, No. 4, April, 1941, pp. 189-194.) (90/47 Great Britain.)

The adoption of machine accounting in an engineering works necessitated the addition to the existing battery of psychological tests for the selection of staff, of reaction time and hand-and-eye co-ordination tests.

Two new instruments, consisting almost wholly of standard telephone components, are described, their operation sequences are given and reference is made to the accuracy of the reaction tester.

The results of the practical tests with these instruments are shown and simply discussed.

The instruments, simple to operate and both accurate and reliable, were adequate for their purpose, and it is suggested that they may have a wider application.

Visibility and Seeing. (M. Luckiesh and F. K. Moss, J. of Franklin Inst., Vol. 231, No. 4, April, 1941, pp. 323-343.) (90-48 U.S.A.)

Visibility is defined as an attribute of the physical characteristics of the object of regard as determined introspectively by an observer possessing normal vision. Therefore seeing may be defined as a function of the visibility of the object and the visual efficiency of the observer. Techniques for the appraisal of visual efficiency have long been available to visual science; and techniques for the appraisal of visibility are needed in illuminating engineering and throughout all

practices involving seeing. The significance of visibility, as a factor in seeing, is presented through the medium of correlations with certain psycho-physiological effects resulting from seeing under conditions which afford various degrees of visibility. These analyses reveal that visibility and ease of seeing are closely related. The frequency of involuntary blinking has been developed as a criterion of ease of seeing and correlated with measurements of visibility. By these correlations, visibility measurements become of the utmost importance in the science of seeing whose most important objectives involve measurements and interpretations in the realm of supra-threshold seeing.

Training of the Aeronautical Engineer in Germany. (G. Doetsch and G. Seidel, Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 14-19.) (90/49 Germany.)

In Germany there are two methods of training aeronautical engineers:— 1. Starting from the elementary schools (after study of special craftsmanship or from the higher schools with the higher or medium school certificate), a two years practical training course at an engineering school is taken, finishing with the technical school engineering examination. This training is intended for practical engineers with sufficient theoretical fundamentals for general work. 2. Starting from the higher schools with the school leaving certificate, a one-year practical course in a works is followed by study at the technical high school, ending with the diploma examinations. This training is intended to provide the scientific and highly qualified engineers for leading positions and research work. Details of craftsmanship and works course are given.

At the technical high schools the study of aeronautics falls into three main branches:—

(*a*) Aircraft construction.

(*b*) Engine construction.

(*c*) Aircraft handling and operation (equipment, armaments, navigation).

The technical high schools include centres at which all three special branches are studied (Berlin, Brunswick and Munich), and those dealing more especially with practical instruction in aircraft construction (Aachen, Danzig, Darmstadt, Stuttgart, and Vienna, aero engines also at Stuttgart). Finally the University of Göttingen, with its chair of applied mechanics, and the Kaiser-Wilhelm-Institut fur Strömungsforschung offer facilities for aerodynamic research. Sample curricula for the various stages of instruction are given. Student flying groups have been organised at various colleges and universities (Flugtechnische Fachgruppen und Flugtechnische Arbeitsgemeinschaften).

U.S.A. Aviation Exports. (American Aviation, Vol. 4, No. 20, 15/3/41, p. 38.) (90/50 U.S.A.)

Great Britain purchased U.S. aviation products totalling $134,543,037 during 1940, or more than 43 per cent. of the year's aeronautic shipments valued at $311,757,326, according to figures released by the Motive Products Division Department of Commerce. Second best 1940 customer for U.S. aeronautic exports was France, whose $75,463,921 purchases represented 24 per cent. of the total value.

The year's exports included 3,532 aircraft valued at $196,352,315; 4,986 engines for $49,873,823; engine parts and accessories $19,724,433; instruments and parts $7,303,386; propellers and parts $9,967,196; parachutes and parts $1,068,779; and other parts and accessories $27,467,394.

The 1940 exports account for 46 per cent. of the grand total value of aeronautic shipments, $677,606,199, since they were first reported separately June 1, 1911.

Value of aeronautic exports to the 14 " million dollar " markets for 1940, as compared with the preceding two years, are shown as follows (to the nearest million):—

	1940 $	1939 $	1938 $
United Kingdom	135	35	4
France	75	42	—
Canada	34	3	4
Australia	16	2	1
China	11	1	6
Netherlands Indies	6	6	8
Sweden	5	—	1
Finland	4	—	—
Union of S. Africa	4	—	—
Brazil	3	2	2
Turkey	2	1	3
Norway	1	—	—
Argentina	1	2	6
Belgium	1	—	—
Percentage of total ...	96	83	55
Number of other markets	70	77	73

A Mechanical Method for Graphical Solution of Polynomials. (S. L. Brown and L. L. Wheeler, J. of Frank. Inst., Vol. 231, No. 3, March, 1941, pp. 223-243.) (90/52 Great Britain.)

A mechanical synthesiser with thirty harmonic elements (fifteen sine components and fifteen cosine components) may be used to graph a polynomial in a complex plane. The sum of the sine components is recorded by a tracing point which moves vertically. The sum of the cosine components is recorded by horizontal motion of a drawing board.

Expansion of the polynomial by De Moivre's theorem expresses the function as a sum of sine terms and a sum of cosine terms. The polynomial may then be graphed by the machine, and thereby the complex roots determined. A number of typical curves are given to illustrate the machine method of determining real, imaginary, and complex roots.

An auxiliary method is described which gives all the real roots of the polynomial from a single graph.

Determination of the Average Life of Vacuum Tubes. (D. K. Gannett, Bell Laboratories Record, Vol. 18, No. 12, August, 1940, pp. 378-382.) (90/53 U.S.A.)

Analysis of many field trials on tubes used in telephone plants has shown that, after an initial period which varies with the types of tube, but is usually about 4,000 hours, the rate of failure expressed in per cent. of tubes remaining in service tends to become constant. In other words, the tubes fail at random and the logarithm of the per cent. of tubes surviving plotted against time results in a straight line, which renders extrapolation easy. If the life curve is accurately exponential, it can be shown that the average life corresponds to the time when about 37 per cent. of the tubes remain in service. Analysis of test results show that it is possible to predict average life on this basis, provided the initial period (for which the exponential law does not hold) has been passed through.

Various types of life curves are illustrated, showing life period varying between 12 and 25,000 hours, depending on type of equipment.

It is interesting to note that the exponential life curve implies that the probable further life of a group of used tubes which are still good is the same as the probable life of a group of new tubes (neglecting initial period). The short lived tubes having been weeded out, there is thus no advantage of replacing the whole set by new tubes.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.), Ministry of Aircraft Production, and copies will be loaned as far as availability of stocks permits. Application should not be made to the Royal Aeronautical Society. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

LIST 32, MAY, 1941.

AERO- AND HYDRODYNAMICS.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND REFERENCE.
1174	Schrenk, O. ...	*Boundary Layer Control by Suction.* (Luftwissen, Vol. 7, No. 12, Dec., 1940, pp. 409-14.)
1175	Ackeret, J.	*The Effect of Compressibility on Air Flow.* (Flugwehr und-Technik, Vol. 2, No. 1, Jan., 1940, pp. 18-20.)

ENGINES AND ACCESSORIES.

1168	Muller, F. O. ...	*Conditions of Acceleration in Spherical Crank Drives and Related Mechanisms.* (Z.V.D.I., Vol. 73, No. 4, 26/1/29, pp. 117-125.)
1169	Englisch, C. ...	*Sealing of Piston Rings in Internal Combustion Engines.* (A.T.Z., Vol. 41, No. 22, 25/11/38, pp. 579-84.) (Translated by the Bristol Aeroplane Company, Ltd.)
1172	Poggi, L.	*Kinematical-Dynamical Studies of a Novel Crank System for Engines with Parallel Cylinders.* (L'Aerotecnica, Vol. 20, No. 5, May, 1940, pp. 374-97.)

MISCELLANEOUS.

1171	Lohner, H.	*Condensation Trails.* (Luftwissen, Vol. 7, No. 10, Oct., 1940, pp. 337-9.) (Translated by S.R.E. Department, Admiralty.)
1173	Gorsky, V. P. ... Chessalov, A. V. ...	*Investigation of Uncontrolled Swerve (Ground Looping) at Take-off in a Cahi-6 Aircraft.* (Aeron. Eng., U.S.S.R., Vol. 12, No. 3, March, 1938, pp. 7-23.)
1176	Meier-Muller, H. ...	*On the Medico-Psychological Aspect of Flying Accidents.* (Flugwehr und-Technik, Vol. 2, No. 1, Jan., 1940, pp. 12-14; No. 2, Feb., 1940, pp. 40-42.)
1177	Schmidt, O. Von ...	*A New Path of Sound Waves in the Atmosphere.* (Luftwissen, Vol. 7, No. 11, Nov., 1940, pp. 382-5.)

LIST 33, JUNE, 1941.

ENGINES AND ACCESSORIES.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND REFERENCE.
1178	Pistolesi, E. ...	*Review of Modern Variable Pitch Airscrews.* (L'Aerotecnica, Vol. 20, No. 10, Oct., 1940, pp. 747-760.)
1181	Riabouchinsky, D....	*Introduction to the Study of Moto-Propulsor Groups Producing Supersonic Velocities.* (D. Riabouchinsky, Pub. Sci. et Tech. du Ministère de l'Air, No. 157, 1939.)
1182	Caroselli, H. ...	*Pressure Cooling for Liquid-Cooled Aero Engines.* (Luftwisse, Vol. 7, No. 11, Nov., 1940, pp. 373-381.)
1197	Hollbach, O. ...	*Aero Engine Accessories.* (Export Handbook of the German Aircraft Industry, 1939, pp. 143-169.)

MATERIALS.

1186	Burger, H.	*Torsional Strength of Motor Car Frames (The).* (Forschung, Vol. 10, No. 4, July-August, 1939, pp. 170-174.)
1190	Ploch, C. H. ...	*Automatic Riveting in Aircraft Construction.* (Luftwissen, Vol. 8, No. 2, Feb., 1941, pp. 36-42.)

MISCELLANEOUS.

1180	Ferrari, C.	*The Determination of the Projectile of Minimum Wave Resistance.* (Proc. Ac. Turin., Vol. 74, 1939, pp. 675-693, and Vol. 75, 1939, pp. 61-96.)
1183	Klanke, G.	*De-icing Experiments on Sail Planes.* (Luftwissen, Vol. 7, No. 11, Nov., 1940, pp. 388-392.)
1184	Hollbach, O. ...	*Navigational Instruments.* (Export Handbook of the German Aircraft Industry, 1939, pp. 125-132.)
1187	Doetsch, G. ...	*The Training of Aeronautical Engineers in Germany.* (Luftwissen, Vol. 8, No. 1, Jan., 1941, pp. 14-19.)
	Seidal, I.	

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING MARCH, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

THEORY AND PRACTICE OF WARFARE.

ITEM NO.		TITLE AND JOURNAL.
75/1	Germany ...	*Focke-Wulf 200K (Kurier) Four-Engined Bomber.* (Aeroplane, Vol. 60, No. 1,552, 21/2/41, p. 215.)
75/2	Italy ...	*Caproni Reggiane Re 200 (Falcho) Single-Seat Fighter.* (Aeroplane, Vol. 60, No. 1,552, 21/2/41, p. 222.)
75/3	Great Britain	*Identification of Aircraft. Comparison of Handley Page "Hereford" and Dornier Do 215.* (Flight, Vol. 39, No. 1,678, 20/2/41, p. 150.)
75/4	Great Britain	*Lessons of the Tactical Employment of Fighters and Bombers in the Present War. IV.* (N. Macmillan, Flight, Vol. 39, No. 1,678, 20/2/41, pp. 155-7.)
75/5	U.S.A. ...	*Export of Aircraft from U.S.A.: American Aircraft Quality and Present Rates of Production and Export.* (B. Foster, Flight, Vol. 39, No. 1,678, 20/2/41, pp. 158-60.)
75/6	U.S.A. ...	*Republic "Lancer" Pursuit-Interceptor.* (Aero Digest, Vol. 38, No. 1, Jan., 1941, pp. 168 and 236.)
75/7	U.S.A. ...	*Mobile Fire-Fighting Unit.* (Aero Digest, Vol. 38, Jan., 1941, p. 212.)
75/8	Great Britain	*New Fleet Air Arm Types (Grumman "Martlet" Single-Seat Deck-Landing Fighter and Fairey "Fulmar" Two-Seat Naval Fighter).* (Airc. Eng., Vol. 13, No. 144, Feb., 1941, pp. 37-9.)
75/9	U.S.A. ...	*The Truth about our National Defence Programme: Why Aircraft Production has Lagged—and How Much.* (T. P. Wright, Aviation, Vol. 40, No. 1, Jan., 1941, pp. 31-3 and 130-8.)
75/10	Germany ...	*Warplane Factories in Germany: The Junkers Diesel Engine Factory.* (P. H. Wilkinson, Aviation, Vol. 40, No. 1, Jan., 1941, pp. 48-9.)
75/11	U.S.A. ...	*Lear Avia "Bale-Out" Siren.* (Aviation, Vol. 40, No. 1, Jan., 1941, p. 70.)
75/12	U.S.A. ...	*Curtiss "Mohawk" and "Tomahawk" Pursuit Planes (P40 and P36A).* Flight, Vol. 39, No. 1,679, 27/2/41, pp. a-c.)
75/13	Japan ...	*Nippon's Air Power.* (Flight, Vol. 39, No. 1,679, 27/2/41, pp. e-174.)
75/14	U.S.A. ...	*American Views on Production Rates in the Present Air War.* (T. P. Wright, Flight, Vol. 39, No. 1,679, 27/2/41, pp. 175-6.)

ITEM NO.		TITLE AND JOURNAL.
75/15	Great Britain	*Blenheim IV and Heinkel He IIIK Silhouettes.* (Flight, Vol. 39, No. 1,679, 27/2/41, p. d.)
75/16	U.S.A. ...	*New Plan for Building Bombers by the Automobile "Big Three"* (*Ford, General Motors, Chrysler*). (Autom. Ind., Vol. 84, No. 2, 15/1/41, pp. 57, 68, 96.)
75/17	Germany ...	*Note on Various Types of Parachute.* (Der Flieger, Vol. 19, No. 11-12, Nov.-Dec., 1940, pp. 298-300.)
75/18	Germany ...	*The Parachute (continued).* (Der Flieger, Vol. 20, No. 1, Jan., 1941, pp. 18-19.)
75/19	U.S.A. ...	*Fire-Extinguishing Effectiveness of Chemicals in Water Solution.* (H. D. Tyner, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 60-5.) (Abstract available.)
75/20	Great Britain	*Fire Detection Devices, with Special Reference to the Detection of Incendiary Bombs.* (J. Inst. Elec. Engs., Vol. 88, Part I, No. 2, Feb., 1941, pp. 88-92.)
75/21	U.S.A. ...	*Army Air Corps Training of Pilots.* (U.S. Air Services, Vol. 26, No. 2, Feb., 1941, pp. 17 and 38.)
75/22	Italy ...	*Breda 65 Attack-Bomber.* (Aeroplane, Vol. 60, No. 1,553, 28/2/41, p. 254.)
75/23	U.S.A. ...	*Boeing 314A Flying Boats.* (Aeroplane, Vol. 60, No. 1,553, 28/2/41, p. 262.)
75/24	U.S.A. ...	*The Four-Engined Boeing B-17B.* (Airc. Prod., Vol. 3, No. 29, March, 1941, pp. 97-101.)
75/25	U.S.A. ...	*Features of the "Tomahawk"* (*Curtiss P.40*). (Airc. Prod., Vol. 3, No. 29, March, 1941, pp. 109-10.)
75/26	Germany ...	*A History of External Ballistics.* (F. Klemm, W.T.M., Vol. 45, No. 1, Jan., 1941, pp. 1-8.) (Abstract available.)
75/27	Switzerland...	*Sound Locators. Fundamental Principles.* (O. Born, Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, pp. 251-5.) (Abstract available.)
75/28	Germany ...	*Training of the German Parachute Troops.* (Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, p. 255.)
75/29	Germany ...	*Junkers Ju 88 Bomber.* (Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, pp. 264-5.)
75/30	France ...	*The Influence of the 24-Cylinder (2,000 h.p.) Engine on the Development of the Fighter Bomber.* (C. Rougeron, Inter. Avia., No. 751, 20/2/41, pp. 1-3.) (Abstract available.)
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75/160	U.S.A. ...	*Beam Column End Moments for Known Fixity Coefficients.* (F. B. Wozniak, Aviation, Vol. 40, No. 1, Jan., 1941, p. 52.)
75/161	U.S.A. ...	*Honing Engine Parts.* (L. S. Martz, Aviation, Vol. 40, No. 1, Jan., 1941, pp. 56-7 and 126.)
75/162	U.S.A. ...	*Nylon for Parachutes.* (Aviation, Vol. 40, No. 1, Jan., 1941, p. 83.)
75/163	Great Britain	*Metal Salvage: Efficient Control and Disposal of Swarf and Scrap.* (D. F. Galloway, Autom. Eng., Vol. 31, No. 407, Feb., 1941, pp. 55-9.)
75/164	U.S.A. ...	*Honed Microfinish for Aircraft Parts.* (Autom. Ind., Vol. 84, No. 2, 15/1/41, pp. 59-62, 96.)
75/165	U.S.A. ...	*Plastics Used in the Fabrication of Larger Parts of Aircraft.* (H. Chase, Autom. Ind., Vol. 84, No. 2, 15/1/41, pp. 63-7, 100.)
75/166	U.S.A. ...	*Symposium on Hardenability of Steels. S.A.E. Annual Meeting.* (Autom. Ind., Vol. 84, No. 2, 15/1/41, pp. 74-8, 81.)
75/167	Great Britain	*Surface Finish: its Effect on the Problems of Friction and Lubrication and its Importance in Aero Engine Manufacture.* (Airc. Prod., Vol. 3, No. 28, Feb., 1941, pp. 41-4.)
75/168	Great Britain	*Resistance Butt Welding.* (Airc. Prod., Vol. 3, No. 28, Feb., 1941, p. 55.)
75/169	U.S.A. ...	*Forming and Stamping Aircraft Parts: A Survey of Press Tool Technique as Practised in America.* (Airc. Prod., Vol. 3, No. 28, Feb., 1941, pp. 59-64.)
75/170	Great Britain	*Turning with Diamond Tools.* (E. Fess, Airc. Prod., Vol. 3, No. 28, Feb., 1941, p. 64.)
75/171	Great Britain	*Welding of Airframes: Part II. Alignment of Fuselage; Assembly of Fin and Tailplane; Elevator and Rudder; Repairs to the Fuselage.* (W. Corns, Airc. Prod., Vol. 3, No. 28, Feb., 1941, pp. 66-70.)
75/172.	U.S.A. ...	*Annealing Atmospheres from the Combustion Products of Gaseous Fuels.* (A. G. Hotchkiss, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 32-8.)
75/173	U.S.A. ...	*Protective Atmospheres for Hardening Steel.* (J. R. Gier, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 38-41.) (Abstract available.)
75/174	U.S.A. ...	*City Gas for Special Atmospheres.* (C. R. Cline and C. G. Segeler, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 46-54.)
75/175	U.S.A. ...	*Gas Carburising by the Hypercarb Process.* (W. A. Darrah, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 54-9.) (Abstract available.)
75/176	U.S.A. ...	*Acid Corrosion of Steel.* (G. H. Damon, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 1, Jan., 1941, pp. 67-9.)

ITEM NO.		TITLE AND JOURNAL.
75/177	Great Britain	*Structural Changes Accompanying Age Hardening.* (Metallurgist, 28/2/41, pp. 3-4.)
75/178	Great Britain	*Flakes in Steel Forgings.* (Metallurgist, 28/2/41, pp. 4-6.)
75/179	Great Britain	*Identification of Light Scrap.* (Engineer, Vol. 171, No. 4,442, 28/2/41, p. 145.) (Abstract available.)
75/180	Great Britain	*Increasing the Ductility of Welds.* (Dawson and Lytle, Steel, 20/1/41, pp. 62-4.) (Met. Vick. Tech. News Bull., No. 750, 21/2/41, p. 7.) (Abstract available.)
75/181	Great Britain	*Electromagnetic Stirring Action in a Spot Weld.* (Unger, Matis and Knocke, Welding Journal, Jan., 1941, pp. 42-7.) (Met. Vick. Tech. News Bull., No. 750, 21/2/41, p. 7.) (Abstract available.)
75/182	Great Britain	*The Welding, Soldering and Brazing of High Nickel Alloys.* (Engineering, Vol. 151, No. 3,918, 14/2/41, p. 124.)
75/183	Great Britain	*60 KVA. Half Cycle Bench Mounting Spot Welder.* (Engineering, Vol. 151, No. 3,918, 14/2/41, p. 130.)
75/184	Great Britain	*The Manufacture and Use of Cemented Carbides.* (H. Burden, Engineering, Vol. 151, No. 3,919, 21/2/41, pp. 145-7.)
75/188	U.S.A. ...	*Statistical Control of Materials and Manufactured Products (with useful bibliography).* (J. Geschelin, Autom. Ind., Vol. 84, No. 3, 1/2/41, pp. 128-9, 139-40.) (Abstract available.)
75/189	Great Britain	*Synthetic Rubber and Plastics I (to be cont.).* (H. Baron, British Plastics, Vol. 12, No. 141, Feb., 1941, pp. 276-8.)
75/190	Great Britain	*Low Temperature Resistant Plastics for Safety Glass.* (British Plastics, Vol. 12, No. 141, Feb., 1941, p. 285.)
75/191	Great Britain	*Recent Investigations of the Dry Cyaniding Process (Surface Hardening of Steel).* (Rudorff, Metallurgia, Feb., 1941, pp. 99-102.) (Met. Vick. Tech. News Bull., No. 751, 28/2/41, p. 5.)
75/192	Great Britain	*Trends in Arc Welding.* (Reddie, Iron Age, 16/1/41, pp. 41-3.) (Met. Vick. Tech. News Bull., No. 751, 28/2/41, p. 5.)
75/193	U.S.A. ...	*Strategic Metals and their Future Supply (Paper to S.A.E. Annual Meeting).* H. W. Gillette and Z. Jeffries, Autom. Ind., Vol. 84, No. 4, 15/2/41, p. 174.)
75/194	Great Britain	*Transparent Coverings (for Cockpits, Turrets, etc.), Machining and Installation of Units Made from Plastic Sheet.* (Airc. Prod., Vol. 3, No. 29, March, 1941, pp. 77-8.)
75/195	U.S.A. ...	*Photographic Lofting: Lockheed Aircraft Corporation's Method for Making Templates and Tooling Layouts.* (Airc. Prod., Vol. 3, No. 29, March, 1941, pp. 85-6.)
75/196	Great Britain	*Investigations on the Spot Welding of Light Alloys (Report of the Welding Research Council of the Institute of Welding).* (G. H. Field and H. Sutton, Airc. Prod., Vol. 3, No. 29, March, 1941, p. 101.)
75/197	Great Britain	*Half-Cycle Bench Mounting Spot Welding Machine for Welding of Small Parts.* (Airc. Prod., Vol. 3, No. 29, March, 1941, p. 104.)

ITEM NO.		TITLE AND JOURNAL.
75/198	Great Britain	*Swarf Control and Disposal: Equipment for Scrap Metal Recovery.* (D. F. Galloway, Airc. Prod., Vol. 3, No. 29, March, 1941, p. 111.)
75/199	Great Britain	*Woven Glass Insulation for Electrical Windings.* (C. D. Jamieson, Engl. Elect. J., Vol. 10, Nov., 1940, pp. 61-5.) (Sci. Absts. " B," Vol. 44, No. 517, Jan., 1941, pp. 11-12.)
75/200	U.S.A. ...	*Similarity of the Stress Distributions in a Circular Disc and a Square Plate.* (H. Okubo, J. App. Physics, Vol. 11, Nov., 1940, pp. 720-3.) (Sci. Absts. " A," Vol. 44, No. 517, Jan., 1941, p. 5.)
75/201	U.S.A. ...	*Stress Analysis by Three-Dimensional Photo-Elastic Methods.* (D. C. Drucker and R. D. Mindlin, J. App. Physics, Vol. 11, Nov., 1940, pp. 724-32.) (Sci. Absts. " A," Vol. 44, No. 517, Jan., 1941, p. 5.)
75/202	Great Britain	*Vibrations of Free Plates: Isosceles Right-Angled Triangles.* (M. D. Waller, Proc. Phys. Soc., London, Vol. 53, Jan., 1941, pp. 35-9.) (Sci. Absts. " A," Vol. 44, No. 517, Jan., 1941, p. 5.)
75/203	U.S.A. ...	*Principles of Jig and Fixture Practice.* (J. W. Roe, Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 117-124.)
75/204	U.S.A. ...	*Iron Base Hard-Facing Metals.* (V. E. Alden, Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 149-51.) (Abstract available.)
75/205	U.S.A. ...	*Preparation of Automobile Bodies for Painting.* (V. M. Darsey, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 2, Feb., 1941, pp. 222-4.) (Abstract available.)
75/206	U.S.A. ...	*Baking Paint with Infra-Red Light.* (J. L. McCloud, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 2, Feb., 1941, pp. 225-30.)
75/207	U.S.A. ...	*The Story of Superfinish (Book Review).* (A. M. Swigert, Lynn Publishing Co., Detroit, 1940, 672 pp.) (J. Frank. Inst., Vol. 231, No. 2, Feb., 1941, pp. 196-7.)
75/208	Great Britain	*Spot Welder Using Magnetic Storage (Sciaky).* (Electrical World, 25/1/41, pp. 44-5.) (Met. Vick. Tech. News Bull., No. 752, 7/3/41, p. 2.)
75/209	U.S.A. ...	*The Column Strength of Closed, Thin-Walled Sections of 18-8 Stainless Steel.* (H. W. Barlow, J. Aeron. Sci., Vol. 8, No. 4, Feb., 1941, pp. 151-61.) (Abstract available.)
75/210	Germany ...	*Safety in Light and Ultra-Light Alloy Manipulation—Explosion and Fire Risks (from the German).* (H. Berger, Light Metals, Vol. 4, No. 38, March, 1941, pp. 44-53.)
75/211	U.S.A. ...	*The Mechanics of Metal Cutting (Review of American and Russian Research).* (Light Metals, Vol. 4, No. 38, March, 1941, pp. 54-5.)
75/212	Great Britain	*Age-Hardening of Magnesium Alloys.* (W. F. Chubb, Light Metals, Vol. 4, No. 38, March, 1941, pp. 60-62.)
75/213	Germany ...	*Steel Studs and Bolts Screwed into Light Alloys—Effect of Bearing Length, Fit and Surface Finish (from the German).* (Light Metals, Vol. 4, No. 38, March, 1941, pp. 63-4.)

ITEM NO.		TITLE AND JOURNAL.
75/214	Great Britain	*Soldering of Aluminium and its Alloys.* (Light Metals, Vol. 4, No. 38, March, 1941, pp. 64-6.)
75/215	U.S.A. ...	*Experience with Metals at High Temperatures for Power Plants.* (A. E. White and C. L. Clark, Trans. A.S.M.E., Vol. 63, No. 2, Feb., 1941, pp. 137-41.) (Abstract available.)
75/216	Switzerland...	*Precipitation-Hardening of Aluminium Alloys.* (A. von Zeerleder, Flugwehr und-Technik, Vol. 2, No. 11-12, Nov.-Dec., 1940, pp. 261-3.)

METEOROLOGY AND PHYSIOLOGY.

75/217	Great Britain	*Sea Breezes at Worthy Down, Winchester.* (S. P. Peters, M.O. Professional Note, No. 86, 1938.)
75/218	Cyprus ...	*Upper Winds at Nicosia (Cyprus).* (J. Durward, M.O. Professional Note, No. 87, 1938.)
75/219	Great Britain	*Fog on the Mainland and Coasts of Scotland.* (F. E. Dixon, M.O. Professional Note, No. 88, 1939.)
75/220	Malta ...	*Abnormal Visibility at Malta.* (A. C. Best, M.O. Professional Note, No. 89, 1939.)
75/221	Great Britain	*The Distribution of Electricity in Thunderclouds (II).* (G. Simpson and G. D. Robinson, Proc. Roy. Soc., Vol. 177, No. 970, 24/2/41, pp. 281-329.) (Abstract available.)
75/222	U.S.A. ...	*Meteorological Effects and their Relation to the Electrical Condition of the Lower Atmosphere.* (G. R. Wait and O. W. Torreson, Bull. Int. Union Geod. and Geophys., No. 11, 1940, pp. 491-500.) (Sci. Absts. "A," Vol. 44, No. 518, Feb., 1941, p. 36.)
75/223	U.S.A. ...	*On a New Method of Measuring the Mean Height of the Ozone in the Atmosphere.* (J. Strong, J. Frank. Inst., Vol. 231, No. 2, Feb., 1941, pp. 121-155.)
75/224	U.S.A. ...	*Daytime Photo-electric Measurement of Cloud Heights.* (J. Frank. Inst., Vol. 231, No. 2, Feb., 1941, pp. 177-8.)

MISCELLANEOUS.

75/225	Canada ...	*Occupational Hazards in the Aircraft Industry.* (Canadian Aviation, Vol. 14, No. 1, Jan., 1941, pp. 40-1.)
75/226	U.S.A. ...	*Abstracts of Papers at the S.A.E. Annual Meeting.* (Autom. Ind., Vol. 84, No. 2, 15/1/41, pp. 70-1, 82-6, 95, 98.)
75/227	Great Britain	*Insect Flight.* (F. S. G. Hollick, Nature, Vol. 147, No. 3,722, 1/3/41, p. 270.)
75/228	U.S.A. ...	*Floating Power Plants for Generating Electricity.* (Mech. Eng., Vol. 63, No. 2, Feb., 1941, pp. 144-5.)

PHOTOGRAPHY.

75/229	Great Britain	*Extragranular Factors in Photographic Sensitivity.* (S. E. Sheppard and C. L. Graham, Commun. Kodak Res. Lab., No. 777, Photogr. J., Vol. 80, Dec., 1940, pp. 470-9.) (Sci. Absts. "A," Vol. 44, No. 518, Feb., 1941, p. 41.)

Sound, Light and Heat.

ITEM NO.		TITLE AND JOURNAL.
75/230	Great Britain	*An Objective Noise-Meter Reading in Phons for Sustained Noises with Special Reference to Engineering Plant.* (A. J. King, R. W. Guelke, C. R. Maguire and R. A. Scott, J. Inst. Elec. Engs., Vol. 88, Part I, No. 2, Feb., 1941, pp. 97-99.)
75/231	Germany ...	*Propagation of Sound from Swiftly Moving Bodies.* (L. Prandtl, Schriften der deutschen Akademie der Luftfahrtforsch., No. 7, 1938-9, pp. 1-10.) (Available in R.T.P.3.)
75/232	Germany ...	*Brief Report on Sound Absorption.* (R. W. Pohl, Schriften der deutschen Akademie der Luftfahrtforsch., No. 10, 1938-9, pp. 27-31.) (Available in R.T.P.3.)
75/233	Germany ...	*New Optical Method for Investigating the Radiation from Sources of Sound.* (E. Hiedemann, Schriften der deutschen Akademie der Luftfahrtforsch., No. 10, 1938-9, pp. 33-8.) (Available in R.T.P.3.)
75/234	U.S.A. ...	*Unsteady Flow of Heat through Porous Media.* (W. D. Harbert, D. C. Cain and R. L. Huntington, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 2, Feb., 1941, pp. 257-63.)

Wireless and Electricity.

75/235	Germany ...	*Wireless Equipment of the Luftwaffe.* (Wireless World, Vol. 46, Nov., 1940, pp. 450-2.) (Sci. Absts. " B," Vol. 44, No. 517, Jan., 1941, p. 18.)
75/236	U.S.A. ...	*Radio Fade-Outs and Their Origin.* (J. N. Bhar, Science and Culture, Vol. 6, Sept., 1940, pp. 150-7.) (Sci. Absts. " B," Vol. 44, No. 517, Jan., 1941, p. 18.)
75/237	U.S.A. ...	*Recent Ionospheric Researches.* (E. V. Appleton, Bull. Int. Union Geod. and Geophys., No. 11, 1940, pp. 516-21.) (Sci. Absts. " A," Vol. 44, No. 518, Feb., 1941, p. 35.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example that published by the Aeronautical Research Committee) is already known to these Staffs.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revenue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).

J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Veroffentlichungen aus dem Gebtete der Nachrichtentecgnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Some Notes on the Ideal Efficiency of Airscrews. (W. Hoff, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 114-121.) (9¼ Germany.)

According to the simple jet theory, the thrust is distributed uniformly over the actuator disc and there are no rotary losses. If the disc is replaced by rotating blade elements, rotary losses cannot be avoided. If it were possible to operate the blade elements at different angular velocities so that ω_r is constant along the blade, the axial losses distributed uniformly over the jet would remain unchanged and the additional rotary losses are also distributed uniformly. Such an arrangement has the greatest possible efficiency. In practice, however, the blade elements necessarily operate at constant ω irrespective of r, and the best thrust distribution with smallest losses is achieved when the induced efficiency of the ring elements varies between an inner and an outer limit. The author compares the resultant efficiency with the ideal case (ω_r constant) and notes a small loss, necessarily associated with the high v/u ratio for elements near the hub (v=translatory and u=circumferential speed).

In conclusion the author's results are compared with other theoretical investigation on lightly loaded propellers and in this connection extensive references are made to Glanert's article on " Airplane Propellers " in Vol. IV of Durand's " Aerodynamic Theory."

Dornier Do 18 Flying Boat Fitted with B.M.W. 132 Air-cooled Radial Engines. (Luftwissen, Vol. 7, No. 12, Dec., 1940, pp. 420-422.) (91/5 Germany.)

The Dornier flying boat was originally fitted with two liquid-cooled Diesel engines (Jumo 205) arranged in tandem on the central section of the wing surface, the front engine being fitted with a tractor airscrew, whilst the rear engine operates a pusher screw through an extension shaft. This arrangement provided small frontal resistance, high efficiency of the pusher screw and good performance when flying on one engine only. Moreover, the Diesel engines had a very small fuel consumption and this contributed to the exceptional range of the boat (record flight of 8,400 km.). With the coming of the war, increasing use was made of the machine for flight of relatively limited range. At the same time, the need for a catapult start was felt to be a drawback. Both these requirements were met by replacing the Jumo engines with 2 B.M.W. radials arranged in tandem as before and completely immersed in one engine nacelle. In this arrangement air enters the front engine in the normal manner through the centre of the cowl and is exhausted through two lateral and controllable ports in the nacelle immediately behind the engine. The cooling air for the rear engine enters a scoop at the rear of the nacelle, is turned through 90° and fed to a cooling fan. The air then impinges on the exhaust side of the rear engine (which is mounted in the reverse direction to the front engine) and after passing the engine is exhausted through a second pair of lateral ports placed behind the first pair. The cooling air stream to the second engine thus moves in a direction opposing that of flight. The two sets of lateral ports are so positioned that no hot air can enter the rear scoop. It is stated that the cooling of both engines is satisfactory and that the assistance of the fan provides sufficient cooling even if the rear engine (working the pusher airscrew) is operated alone.

The performance of the boat has been vastly improved since the change in engines. Whilst before an all up weight of 10 tons required a catapult start, weights up to 13.5 tons have been lifted without take-off assistance. In spite of the power absorbed by the cooling fan, the increased efficiency of the pusher screw is such that, for single engine take-off, the near engine alone will lift 400 kg. more than the front engine.

The relative power outputs of the old and new engines is given in the following table :—

	Take-off h.p.	Cruising h.p.	Sp. fuel consumption gm./b.h.p. hour.	Weight/power ratio kg./h.p.
Junno 205 ...	600	510	165	0.87
B.M.W. 132...	850	630	215	0.56

Material Investigations on Steel Fittings and Structural Parts of Some Captured British, American and French Aircraft. (H. Cornelius, Luftwissen, Vol. 8, No. 3, March, 1941, pp. 78-81.) (91/6 Germany.)

The steel parts examined were taken from the following aircraft :—

British : Blenheim, Wellington, Hampden, Battle, Spitfire.
U.S.A. : Hudson.
France : Morane, Lioré-Olivier.
And covered wings, fuselage, engine supports, landing gear and armour plating.

Attention is called to the extensive use of high alloy Ni-Cr-Mo steels by the British and French. According to the author, equivalent performance can be obtained without Ni, and the resulting Cr-Mo steels have the additional advantage

of being weldable. This is the German and also the American practice. It appears that welding is still not favoured by the British designer. British armour plate varies in thickness from 4.3 to 9.3 mm., with high Ni content (3.1 to 3.9 per cent.). The Fairey Battle used a non-magnetic Mn steel which is totally unsuitable for armour plating on account of its brittleness under bullet impact.

Automatic Riveting in Aircraft Construction. (C. H. Plock, Luftwissen, Vol. 8, No. 2, Feb., 1941, pp. 36-42.) (R.T.P. Translation No. 1,190.) (91/7 Germany.)

The article deals with flush riveting as practiced by the Focke-Wulf Company. Such rivets can either be of the mushroom or flat head type. In the former, the rivet is inserted from the inside and the countersunk head produced from the rivet shaft, previously cut to the exact length to produce a flush fit in the dimpled sheet. The flat head rivet is inserted from the outside, the closing head being produced on the inside without requiring exact dimensioning of rivet length. In plates over 1.2 mm. thickness, the countersink is normally produced by a special tool akin to a milling cutter, the operation being usually combined with the drilling of the rivet hole. For thinner plates, the necessary deformation for the countersink is produced mechanically (dimpling) either by the rivet itself or by means of special tools. If a thin outer skin is to be attached to a thicker plate, the latter is machine countersunk whilst the former is pressed to shape again either by the rivet itself or by a special tool prior to insertion of the rivet. Dimpling by means of the rivet is more economical, but the special tool furnishes a smoother surface. In the simple riveting machine, the operation is limited to the closing of the rivet, either by gradual pressure (air, oil, or a combination), a single blow or multiple blows. A semi-automatic riveting machine combines insertion with dimpling and clenching in one operation. An " automatic " riveter includes drilling the hole, whilst a fully automatic machine also incorporates a work feed. It is also possible for the machine to manufacture the rivets as wanted by cutting off suitable lengths of wire carried on a reel. Representative type of semi and fully automatic machines are illustrated, and an interesting optical device for facilitating alignment of rivet with previously drilled holes is described.

Whilst the simple closing press requires but little operative skill, automatic riveting machines are much more delicate and trained personnel is essential. In the author's opinion, however, the saving in time is such that the high first cost of the automatic is well worth while.

Efficient Design. (Luftwissen, Vol. 8, No. 2, Feb., 1941, pp. 48-49.) (91/8 Germany.)

In the past, production has been increased by employing more labour and working longer hours. Much can, however, be done by efficient design, which not only makes the labour more productive but also saves valuable material. Thus the Dornier works make considerable use of welded steel fittings for wings. Previously such fittings were made of die forgings, and in an example illustrated the original forging weighed 0.65 kg. reduced to 0.28 kg. after machining. By altering the design so that the flange consisted of two portions welded together, the quantity of material required was reduced to 0.20 kg. whilst the time taken to produce the finished article was 40 per cent. less. Tests have conclusively proved that such welded fittings are fully equal to the original product machined out of the solid. Another big saving in time and material can be brought about by the substitution of pressings for previously riveted wing ribs.

It is stated that by introducing 30 small design improvements of this type in a certain aircraft, 90 man hours were saved in labour and the finished machine weighed 42 kg. less, combined with a further saving of 64 kg. in material utilised.

The Influence of Bending and Buckling on Stress Measurements Carried Out on Shell Structure of which Only One Side is Accessible. (A. Dose, L.F.F., Vol. 18, No. 2-3, 19/3/41, pp. 95-101.) (91/9 Germany.)

Stress calculations based on extensometer measurements carried out on the surface of stressed skins can be seriously affected by the even slight buckling of the skin. The corresponding extension due to bending can be eliminated if extensometer measurements are carried out on both sides of the skin. In many cases, however, the interior of the structure is not accessible and it is important to estimate the necessary correction by means of measurements confined to the outer surface.

On the assumption that the bulge is of circular shape, the corresponding strain $\epsilon = d/2 \times 1/R$ where d = thickness of skin and R = radius of curvature of the neutral fibre. The latter can be determined by measuring the height f of the bulge above a chord of length s. Provided f is small and $df/(s/2)^2 < 1$,

$$\epsilon = \frac{df}{(s/2)^2}$$

to a high degree of accuracy.

It is obvious that f can be measured by means of a suitably geared mechanical pointer similar to the spherometer employed in lens measurements and the author has incorporated such a device in the standard Huggenberg extensometer. In this case the extensometer base line coincides with the chord for the f measurements and corrections have to be applied to the strain determination in order to take into account the change in chord length with buckling. These corrections are tabulated by the author. The effect of a bulge of varying curvatures is also investigated. It appears that such changes can generally be neglected if the base line is less than 20 mm. in length. In conclusion, the author gives an example of the effect of buckling on stress distribution in the web of wing spar. (Light alloy skin, 0.75 mm. thick.) The table summarises the results.

	Uncorrected.	Ditto, corrected for buckling.
Principal stress σ_1 ...	-1060 kg./cm.^{2}	-678 kg./cm.^{2}
σ_2 ...	$+460$ kg./cm.^{2}	$+558$ kg./cm.^{2}
τ_{max} ...	760 kg./cm.^{2}	618 kg./cm.^{2}
α ...	-36.4°	-37.5°

The Landing Process (Length of Run, Braking Effort and Possibility of Tipping Over). (G. Matthias and R. Schaeff, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 70-76.) (91/10 Germany.)

The principal object of the author is to determine the factors controlling the landing energy which must be absorbed by the brakes. The danger of tipping (nosing) over is also investigated. Other things being equal, the length of landing run varies as the square of the touch down speed. The principal factors influencing the run are the air resistance, weight, ground friction and brake operation. If a maximum length of run is stipulated for a given wing area and lift coefficient, the kinetic energy to be absorbed by the brakes varies as the square of the aircraft weight (fourth power of landing speed), besides depending on the air forces and friction coefficients during the run. The ratio of lift coefficients at touch down and during rolling on the ground is of primary importance and requires careful consideration when comparing the landing properties of nose wheel and tail wheel aircraft. Even if the brake operation is not limited by the heat generated, the possibility of nosing over puts an upper limit to its braking effort. Nosing over will occur if the ratio (total frictional force)/(weight) becomes greater than the tangent of the angle between the vertical and the line joining the point of contact of the main landing wheels with the C.G. of the aircraft. At the beginning of the run, the lift reduces the effective retarding forces and the danger of nosing over thus only arises towards the

end of the run. The shortest landing run is obtained if the brakes are fully on at touch down and then gradually released so that (retarding force)/(weight) is always just smaller than the tangent of the above mentioned angle.

In the German Safety Regulation for Aircraft, the minimum value of this angle is fixed at 12° for the most forward position of the C.G., the longitudinal axis of the aircraft being assumed horizontal. According to the author this should be modified to cover the fuselage altitude corresponding to three-point landing.

Rate of Vertical Descent after Flattening Out Prior to Landing. (J. Carsens and H. Schaeffer, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 77-81.) (91/11 Germany.)

The aircraft is assumed to be moving horizontally at a velocity v_o so that

$$v_o^2 = G/c_a\,(\rho/2)\,F$$

where c_a = lift coefficient.

G = weight.

F = wing area.

There is no propeller thrust and the subsequent motion of the C.G. is investigated on the assumption that the angle of incidence remains constant, *i.e.*, c_w/c_a is independent of the path angle γ (c_w = drag coefficient).

The resulting equations of motion are integrated by the step by step method with the help of auxiliary functions and the rate of vertical descent v_z after a loss of altitude z as well as the corresponding path distance s along the trajectory are expressed graphically as functions of v_o and z with c_w as parameter. For the practical range c_a at which flattening out should take place, the expression

$$v_z = \sqrt{\frac{c_w}{c_a}2\,gz}$$

holds with good approximation. The actual rate of descent does not increase indefinitely with z, but oscillates with gradually decreasing amplitude about a terminal value. A worked out example for the Fw. 159 aircraft gives the following results:—

$G = 2{,}250$ kg.
$F = 20.2$ m.^{2}
$c_w/c_a = 0.152$
$c_a = 1.70$
$v_o = 31$ m./sec.
} Flaps down, landing wheels out.

z	v_z	s
2	2.3	72
4	3.5	95
8	5.0	120
12	5.7	130
20	6.6	175
28	7.4 (max.)	202
36	7.0	270
40	6.6	260
50	4.8	318
~ 150	4.6 (terminal)	—

Dynamic Balancing of Airscrews. (Esher Wyss, Inter. Avia., No. 754-55, 15/3/41, pp. 10-11.) (91/12 Switzerland.)

The Escher Wyss Maschinenfabriken A.G., of Zurich, Switzerland, carry through the dynamic equilibration of their airscrews on a new type of test bench on which the airscrew is attached on a cantilever mount and supported on one side only. As a result, undisturbed flow conditions such as prevail around the

airscrew mounted on the aeroplane are obtained and sources of error of conventional equilibration benches eliminated. The aerodynamic unbalance of the airscrew may be of the same magnitude as the mechanical unbalance caused by weight differences, the position of the axis and the blades' centre of gravity paths and is caused: (1) By small irregularities in the finish of the airscrew blades as well as the latters' angle of incidence. This type of unbalance could be separated from the mechanical type only by test runs in a vacuum chamber; together the two types result in a sinuous form of oscillation. (2) By the surroundings of the airscrew, *i.e.*, by irregularities in the air flow. The disturbances in the air flow in the vicinity of the airscrew cause, besides the fields of vorticity not depending upon the airscrew speed, pressure shocks every time a blade passes through the disturbed region; these shocks result in an oscillation corresponding to the number of blades and superimposed on the sinuous oscillation. These interfering oscillations may assume such a magnitude as to prejudice the calculation of the measuring results. The oscillations are measured by Escher Wyss not by mean value calculation but by direct optical observation, which provides a very reliable means of determining dynamic unbalances even in the region of great interference amplitudes.

Permanent Buckling Stress of Thin Sheet Panels Under Compression. (W. L. Howland and P. E. Sandorff, J. Aeron. Sci., Vol. 8, No. 7, May, 1941, pp. 261-269.) (91/18 U.S.A.)

In this report it has been shown that:—

1. The problems of skin buckles are of increasing importance to the airplane designer, particularly with high design stresses, low design load factors and greater aerodynamic efficiency.

2. The computed critical buckling stress has practical significance only once in the history of the structure.

3. Structure which buckles in service should be designed so that it will be free of objectionable buckles at a load factor of from 1 to 1.25 after the application of maximum anticipated service load.

4. Theoretical computations indicate a relation between the maximum stiffener stress for objectionable buckling and the critical buckling stress, and this relation is substantiated by experimental data.

5. In applying data on skin buckles to the design of monocoque structures, it is necessary to determine the relation of the stress at maximum service load to that at a load factor of 1.25. This can be expressed through a ratio of panel loads. For buckling materials, an accurate value of panel load is obtained through the use of van Kármán's effective width relation.

6. The relation of the maximum stiffener stress to the critical stress for objectionable buckling can be expressed by a family of curves as in Figs. 9 and 10.

Directional Stability and Vertical Surface Stalling. (G. S. Schairer, J. Aeron. Sci., Vol. 8, No. 7, May, 1941, p. 270.) (91/19 U.S.A.)

A vertical tail stall can only be obtained by yawing the aeroplane to angles at which fin stalling or rudder force reversal or both are obtained. This seldom occurs at less than 15° of yaw. Large aeroplanes are never yawed to any appreciable extent in normal operation and vertical tail stalls are never encountered in normal operation. On some classes of aeroplanes the use of the sideslip manœuvre is desirable, but even on these aeroplanes the sideslip angles normally used would not ordinarily produce a tail stall. Multi-engined aeroplanes, when operated with unsymmetrical power, are frequently flown with some yaw or sideslip, but even then the angle of yaw normally used will not produce a tail stall. There are probably only three ways in which an aeroplane is likely to be yawed sufficiently to produce a tail stall. These are as follows:—

1. Inadvertent engine failure at extremely low speeds on multi-engined aeroplanes on which the rudder is either incapable of supplying all the required restoring moment, or its action is delayed by the human element.
2. Inadvertent excessive sideslipping of manœuvrable aeroplanes.
3. Intentional excessive sideslipping for experimental, educational and other reasons.

On the original version of the Stratoliner at an angle of yaw of about fifteen degrees a noticeable reversal in the pedal force required to produce yaw was measured. This was as noticeable under symmetrical conditions as with one engine dead. The wind tunnel tests of this configuration showed no evidence of a fin stall, but did show a marked loss in stability with the rudder free at between ten and fifteen degrees of yaw.

A new tail surface including a dorsal fin was fitted to the machine and extensive flight tests carried out. At ninety miles per hour with the engines operating at take-off power, the left outboard engine was suddenly throttled. No rudder correction was made and equilibrium in yaw was reached at thirty degrees of yaw. The aeroplane has been flown with both left-hand engines throttled and the right engines at rated power at speeds below 85 miles per hour at zero yaw.

Adequate directional stability has been demonstrated repeatedly by simulating an engine failure during a landing approach with flaps full down at speeds below 85 miles per hour. While in this condition, the throttles on all engines except the left outboard engine are opened, the aeroplane is placed in a climb, and the landing approach abandoned. This is probably the supreme test for any aeroplane. A four-engine aeroplane would be a little safer than a two-engine aeroplane if it did not have the directional stability and control characteristics necessary to make such a manœuvre.

The Stressing of Circular Frames in Shell Structures. (H. Fahlbusch and W. Wegner, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 122-127.) (91/20 Germany.)

The author investigates the stress distribution for frames of constant bending stiffness under four fundamental load conditions:—

A. Localised radial force acting on the frame.
B. Localised moment acting along a diameter of the frame.
C. Localised tangential force acting along the neutral fibre of the frame at a distance r from the centre.
D. Localised tangential force acting along the outer periphery of the frame at a distance R from the centre (=distance of shear flux in shell from centre).

The distribution of bending moment, normal and lateral forces are given in a series of diagrams.

Any arbitrary load can be built up from the above standard cases and the resultant stress distribution obtained by superposition, provided that:—

1. The depth of the circular frames is small compared with r.
2. The cross-section remain plane.
3. The influence of the longitudinal and lateral force on the displacement factors can be neglected.
4. The bending stiffness of the shell is small compared with that of the frame.
5. The frames remain practically circular.

A worked out example illustrates the method.

Aerodynamic Forces Acting on the Wing-Aileron-Tab Combination when Undergoing Harmonic Vibration. (F. Dietz, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 135-141.) (91/21 Germany.)

This is an extension of a previous paper by the author published in L.F.F., Vol. 16 (1939), pp. 87-96, and which covered the two-dimensional case of the

wing-aileron-tab on the supposition that the leading edge of both aileron and tab coincide with the axis of rotation. The formulæ already obtained are reformed so as to apply to the case of aerodynamic balanced surfaces, portions of the equivalent doubly hinged flat plate in front of the hinges, thus forming part of the aileron and tab respectively. These hinges, of course, will not in general coincide with the axis of rotation of either aileron or tab. This conception seems permissible provided the gap between wing and aileron or aileron and tab is small and that the total wing profile is not much affected by the deflection of aileron and tab.

Expressions for the resulting aerodynamic forces are given in tabular form, the use of which is illustrated by a worked out example. The case of a wing aileron combination undergoing harmonic vibrations varying between 0 and 160/sec. at airspeeds of 80 and 160 m. per sec. respectively is considered for two cases of hinge position, (*a*) hinge coincides with leading edges of aileron, (*b*) axis of rotation of aileron is situated at 1/5 chord behind leading edge. It appears that the reduction in aerodynamic moment with displacement of axis of rotation is practically independent of vibration frequency or air speed.

Design of Blade Feet for Airscrews. (G. Cordes, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 128-134.) (91/22 Germany.)

The stressing of modern airscrews is steadily increasing due to the large h.p. employed and the increasing utilisation of the airscrew as a brake during high speed power dives. Not only must the hub be strong enough to carry the heavy loads, but even small deformations must be avoided as they may cause difficulties in the operation of the pitch changing mechanism. In addition the blade feet are subjected to a combination of static and dynamic load requiring careful investigation. The alternating stresses constituting the dynamic load are mainly induced by the engine torque variation, whilst the static load (combination of centrifugal and aerodynamic forces) depends on the operative conditions of the airscrew (take-off, normal flying, driving with engines throttled or full power dives with airscrew acting as a brake).

If

S_o = static thrust of complete propeller,
M_d = mean engine torque,
z = number of blades,
S = thrust per blade,
T = circumferential force per blade at 0.7 R,

we have

$$S = sS_o/z$$

$$T = t\frac{M_d}{0.7\,Rz}$$

when s and t are factors depending on operative conditions.

In addition we have:—

$$M_{dw} = aM_d$$

where M_{dw} = torque fluctuation at propeller shaft and a = constant depending mainly on the damping in the circuit. With the use of D.V.L. data on fatigue limits, the author works out minimum blade feet diameters as a function of h.p. absorbed for blades made of dural, electron and wood respectively.

Four different operative conditions are considered in each case corresponding to take-off and power dives for two values of the torque fluctuation, the corresponding values of the constants being given below:—

Case.	a	s	t
1	±0.5	1	1
2	±0.5	2	1
3	±1.0	1	1
4	±1.0	2	1

(1) and (3) correspond to take-off; (2) and (4) are power dives with propeller acting as a brake.

$a = \pm 1.0$ is representative for current engine installations; the smaller value of "a" can be obtained by efficient damping.

The results are given in a series of curves, from which the following values have been extracted for load case 3.

			H.P absorbed by complete propeller. Wood.	Electron.	Dural.
Effective blade foot diameter	140 mm.	$z=3$	1150	1400	1600
		4	1430	1700	2000
		5	1700	2000	2500
Effective blade foot diameter	160 mm.	$z=3$	1560	1850	2300
		4	1960	2300	2850
		5	2340	2750	3400

On the supposition that the hub is sufficiently strong the safe h.p. during a power dive with the airscrew acting as a brake is only 10 per cent. less than the figure given.

Reducing (a) from ± 1 to ± 0.5, increase the safe h.p. by about 50 per cent. under take-off conditions, but by only 20 per cent. when using engines as a brake during power dives.

Speaking generally, a propeller designed for take-off conditions will not absorb the same power when acting as a brake during a dive, unless either the number of blades or the blade foot diameter is increased.

From the point of view of production, the latter alternative is recommended.

Material and Design of Some Captured British, American and French Aero Motors. (P. Kotzschke, Luftwissen, Vol. 8, No. 3, March, 1941, pp. 69-78.) (91/23 Germany.)

The engines examined covered the following types:—

British: Merlin, Mercury, Hercules, Tiger.
French: Hispano, Gnome-Rhone.
U.S.A.: Cyclone, Twin-Wasp.

All the highly stressed parts (crankshaft, connecting rods, bearings) were carefully examined as to composition and heat and surface treatment. The survey also included cylinder liner, piston rings, valves, valve seating, springs, gears and cylinder bolts. A special section is reserved for light alloys (pistons, cylinder heads and crankcase). (The Cyclone is the only engine examined possessing a steel crankcase.)

Special attention is called to the French process of die casting cylinder heads, which is described in some detail. The author is of the opinion that British and French designers use needlessly complex alloy steels containing varying proportions of Cr, Ni, Wo, etc. Low alloy steels give equivalent performance, as is also recognised by America. Whilst nitriding appears to be more common than in German designs, the author considers that the surface finish is generally below the German standards.

Three New Aero Engines of the B.M.W. 132 Series. (Luftwissen, Vol. 8, No. 2, Feb., 1941, pp. 57-59.) (R.T.P. Translation No. 1,204.) (91/24 Germany.)

The three engines described are known as Mark F, K and N respectively and are further developments of the well known 132 series, 9-cylinder radial, bore = 155.5 stroke = 162.0 mm. The main improvements concern increased finning of the cylinder head round the exhaust valve port (the inlet valve port has no fins), the substitution of epicyclic reduction gears of the spur wheel type for the conical level gear and the fitting of fully automatic fuel injection pumps. Details of the general lay out of the engines and reduction gears are given. It

is stated that the cooling of the engine has also been improved by a new system of baffles attached to the outer ring cowling in such a way as to reduce flow losses to a minimum. No details of the cowling are given. Two valves per cylinder are fitted, inclined at 70°, the exhaust valve being sodium cooled. Both valves are fitted with a special spring clip to prevent the valve dropping into the cylinder in case of spring failure.

The auxiliary drives for injection pump, magneto, generator, air compressor, rev. counter and airscrew governor are neatly arranged on a separate plate at the rear of the engine.

Models F, K and N differ as regards supercharge layout and are rated as follows:—

	F	*K*	*N*
Maximum h.p. take-off ...	800	960	865
Continuous output ...	650	690	665
At altitude (M.)	4,300	1,800	4,500

Couplings and Clutches for Power Plant Machinery. (Engg. and B.H. Rev., May, 1941, pp. 352-358.) (91/25 Great Britain.)

This article gives particular prominence to the problems connected with the alignment of shafts in power plant drives, and formulæ are derived for correcting misalignment. The features and characteristics of a wide range of couplings for turbo-alternators and auxiliary drives of all kinds are dealt with to some length. (Abstract supplied by Research Dept., Met. Vick.)

Air-cooled v. Liquid-cooled Aircraft. (J. G. Lee, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, p. 219-229.) (91/27 U.S.A.)

Data are presented on the drag, weight, cooling and fuel consumption of air-cooled and liquid-cooled power plant installations. Based upon these data the design of three groups of air-cooled and liquid-cooled aeroplanes is postulated. When these groups are compared upon a basis of equal size and weight, the air-cooled aircraft are found to be superior in the pursuit, bomber and transport types. In the author's words: "The U.S.A. are in an extremely fortunate position to have in production 2,000 h.p. air-cooled engines—30 per cent. more powerful than anything available abroad. The foreign nations would match them if they could, but they are learning, as some Americans have already learned, that to develop a really satisfactory 2,000 h.p. liquid-cooled engine is truly a monumental task."

Possibilities of the Two-Stroke Cycle for Small Aircraft. (A. R. Rogowski, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, pp. 230-235.) (91/28 U.S.A.)

In order to reduce the first cost and maintenance of the small aeroplane, and thus making private flying universally available, there is need for a simple, reliable, low-cost engine performance equal to the present four-stroke unsupercharged power plant. The piston-ported loop-scavenged two-stroke engine is considered for this purpose, using as a basis the results of tests on an experimental cylinder of this type. It is concluded that this engine would be most satisfactory, provided the fuel consumption at high outputs could be reduced by means of relatively inexpensive fuel-injection equipment.

The Dynamic Absorber and its Application to Multi-Throw Crankshafts. (Bailey and Bullied, J. Inst. Mech. Engrs., May, 1941, pp. 73-82.) (91/30 Great Britain.)

The dynamic absorber is stated to be the special case of a tuned absorber in which the natural frequency of oscillation is directly proportional to the rotational speed of the shaft which carries it. Four typical absorbers are studied in detail. In each case the tuning and amplitude equations are derived and, for

the roller types, expressions are obtained for the maximum roller amplitude which may be attained without the occurrence of slipping. It is stated that the method is quite general; and can be applied to any other type of engine as desired.

(Abstract supplied by Research Dept., Met. Vick.)

Method of Computing the Dimensions of Airplane Engine Coolers. (J. K. Thornton and J. G. Beerer, J. Aeron. Sci., Vol. 8, No. 7, May, 1941, pp. 292-299.) (91/31 U.S.A.)

A theoretical analysis of the aeroplane engine air-air intercooler has been developed. As a result of this study, three simultaneous equations are obtained, which are solvable for the three linear dimensions of the intercooler. Certain constants in these equations can be obtained only from experimental tests data of the particular type of cooler under consideration. However, once these constants have been obtained, then the size of intercooler required to satisfy a given set of operating conditions may be correctly predicted.

The operating conditions are determined by specifying the following values:— (1) Engine air weight flow, initial temperature and pressure, required temperature drop and allowable pressure drop; (2) cooling air weight flow, initial temperature and pressure and allowable pressure drop.

If all these conditions are fixed, then the dimensions and volume of a given type of intercooler satisfying them are uniquely determined.

But in a practical case, considerable latitude may often be taken in the value of the weight flow of cooling air, in which case many different intercoolers will satisfy the remaining operating conditions. As the weight flow increases, all three dimensions of the intercooler change, but in such a manner that the volume decreases, consequently the final choice must be a compromise between the space available for the intercooler, the weight of the intercooler and ducting problems.

Analysis of the experimental and structural data of a commercially available intercooler gave the necessary coefficients for this type of cooler. These coefficients were inserted in the theoretical equations and then, assuming operating conditions corresponding to the test data, the equations were solved for dimensions and volume. The volumes computed in this manner, checked within 6 per cent. of the volumes used in the test data.

Identification of Oils by Means of Interfacial Surface Tension Determinations (Oil/Water or Oil/Aqueous Solution). (F. Seclich, Fette and Seifen, Vol. 48, No. 1, Jan., 1941, pp. 15-20.) (91/32 Germany.)

All liquids are subject to internal pressure due to intermolecular attraction. As a result the liquid tends to occupy the smallest possible space and any attempt to increase the surface of the liquid is resisted by the force of surface tension. In the case of mixtures, the surface layer will consist predominantly of those molecules which have the least intermolecular attraction, the more " active " molecules being relegated to the interior. Thus the addition of oleic acid (characterised by polar molecules of high internal pressure) does not markedly change the surface tension of paraffin oil (low internal pressure). If, however, instead of determining the surface tension in air (as is usual) the interfacial surface tension of such mixtures against water or aqueous solutions is determined, a large reduction (especially for the first minute additions) is observed. The effect does not only depend on the nature of the " active " constituent present, but also on the time, temperature and exposure to light. The author suggests that investigations of this type not only throw light on questions of molecular constitution and stability of emulsions, but are also useful in checking constancy of oil supplied to specification, degree of refining, etc. For this purpose the author has designed an interfacial tensometer based on an instrument previously described by Lecomte du Norry (J. Gen. Physiol., Vol. 7, 1925, p. 625). In this

instrument the force exerted by the interfacial layer on a platinum ring is measured by means of a torsion balance. The main difference between the author's and the original instrument consists in the fact that the critical force is now measured without breaking the film. It has been found that the breaking away of the ring from the film is never sudden but always preceded by a so-called " super-tension " phase, during which extension of the film is not accompanied by any further increase in the reading of the balance. By means of a simple optical device the approach of this stage is indicated and repeated readings can then be taken over long periods on the same film. (If the film breaks, the ring will traverse the oil and will have to be cleaned before reinsertion.)

Relationship of Viscosity to Rate of Shear. (L. J. Bradford and F. J. Villforth, Trans. A.S.M.E., Vol. 63, No. 4, pp. 359-362.) (91/33 U.S.A.)

This paper reports tests designed to check the validity of the assumption that lubricating oils belong to the class of a Newtonian fluid, which is defined as one in which the force required to shear it is directly proportional to the rate of shear. It is on this assumption, which in recent years has been questioned, that equations for the behaviour of bearings have been based. Experimental evidence is produced in support of Petroff's equation which states that the torque required to rotate a journal, concentric with its bearing, is directly proportional to the product of the absolute viscosity and the rate of shear of the fluid separating the journal and the bearing. The agreement of the results with those predicted by the Petroff equation upon the assumption of the independence of viscosity from the rate of shear holds for all of the oils investigated.

The Effect of Holes Provided with Screw Threads or Longitudinal Serrations on the Endurance and Fatigue Strength of Flat Light Alloy Strips. (H. Burnheim, L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 102-106.) (91/34 Germany.)

The alloy strips (6 mm. thick) were made of dural and electron respectively and were tested under pulsating load (0 to max.) at a frequency of 25 cycles per sec. Wohler curves of max. stress on a basis of total load cycles required for fracture were plotted over the range of 10^4 to 10^7 cycles. After 10^7 cycles, the curve becomes practically horizontal, *i.e.*, the fatigue limit is reached and the corresponding stress variations can be supported indefinitely. The higher stresses corresponding to smaller number of permissible load cycles are called " endurance " stress. Experiments were carried out with undrilled and drilled strips, the holes being either plain, threaded, or serrated. The effect of loading the holes by means of a transverse pin was also investigated. In addition to endurance and fatigue limits, the ratio of endurance of plain sample to drilled sample as well as the ratio ultimate tensile of sample to endurance was determined over a range of load cycles. The former ratio is defined as the notch sensitivity β_k, and is a maximum for both materials for the serrated holes. β_k for the threaded hole is greater than for the plain hole. The relative order of β_k is the same whether the holes are pin loaded or not, but the absolute values are considerably greater in the former case.

For dural β_k does not vary much with number of load cycles (*i.e.*, over the range endurance-fatigue) provided the holes are not pin loaded (average value 2). In the case of pin loading, β_k increases from about 2 to 4 over the load cycle range 10^4 to 10^7.

For electron (unloaded holes) β_k varies from 2 to 3 over the same load cycle range, but from 2.5 to 9.5 in the case of pin loaded serrated holes.

Similarly, over the load cycle range 10^4 to 10^7 the ratio of ultimate tensile to endurance increases from about 3 to 21 from pin loaded serrated holes in the case of magnesium, but only from 3 to 14 for the corresponding case of duralumin.

It is therefore concluded that pin loaded points of electron are unsatisfactory if the holes are serrated. The following table gives the strength characteristics of the plain (undrilled) material.

	Dural.	Electron.
Ultimate tensile, kg./mm.^{2}	42.6	31.5
Yield point, kg./mm.^{2} (permanent extension 0.2 per cent.)	29.4	21.5
Extension, per cent. ($l/d=5$)	19.9	14.4
Fatigue strength, kg./mm.^{2}	15.0	14.0

A New Use for X-Rays in Industry. (Woods and Kenner, Electronics, April, 1941, pp. 29-31.) (91/36 Great Britain.)

Particulars are given of an industrial process which uses the ionisation of air caused by the presence of X-rays to pass a minute current which controls a pass-or-reject relay. This new process is automatic in operation and it is suggested that for inspection of large numbers of articles it will prove more efficient and practical than the normal visual fluorescent inspection methods. The apparatus described is stated to be readily capable of inspecting 1,400 table knives an hour.

(Abstract supplied by Research Dept. Met. Vick.)

Effect of Temperature on Coiled Steel Springs Under Various Loadings. (F. P. Zimmerli, Trans. A.S.M.E., Vol. 63, No. 4, May, 1941, pp. 363-368.) (91/37 U.S.A.)

In the author's opinion the experiments justify the following conclusions:—

1. The usual spring steels are reliable when stressed 80,000 psi or less up to temperatures of 350 F. Between 350 F and 400 F and, at stresses up to 120,000 psi, the same continuity of results is lacking, but with proper forethought some commercial success might be expected.
2. The use of ordinary spring steels over 400 F is not possible.
3. Steels, hardened and tempered after coiling into springs, at the same hardness value, have no advantage over springs made of pretempered wire properly blued, under the conditions investigated.
4. Stainless steel of the 18-8 type resists temperature and stress better than other spring steels, except perhaps high-speed steel.
5. A middle hardness range in quenched-and-drawn springs is preferable to either high or low ranges.
6. An optimum temperature to heat springs after coiling for heat resistance is the highest one which will not render the hardness or other physical properties of the material objectionable.
7. The present Swedish valve-spring wire stands heat very poorly, in fact, is less satisfactory than many other steels.
8. Both high manganese and silicomanganese steels equal the chrome-vanadium steel tested and may have commercial advantages.

Unit Method of Beam Analysis. (F. R. Shanley and F. P. Cozzone, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, pp. 246-255.) (91/38 U.S.A.)

Various improvements in the methods of analysis for determining axial and shear stresses in box beams have been combined into a practical tabular method which permits a considerable saving of time. The method also eliminates some of the errors often made through injudicious use of the classical methods of analysis and offers a means of extending the process to include secondary effects, such as caused by " shear lag " and cutouts.

Fabric Bearings. (Procter, Mech. World, 30/5/41, pp. 369-370-380.) (91/39 Great Britain.)

The question of lubrication is considered, and it is stated that bearing pressures up to 6,000 lb. per sq. in. have been dealt with successfully by suitable lubrication with water and grease. For light loads graphitic impregnation without external lubrication may be employed. Mention is made of the application of fabric linings to footstep and collar thrust bearings.

(Abstract supplied by Research Dept. Met. Vick.)

X-Ray Analysis in Industry. (J. Sci. I., May, 1941, pp. 69-102.) (91/40 Great Britain.)

This issue contains the first part of a symposium on X-ray analysis in industry sponsored by the Institute of Physics. The industrial applications of X-ray analysis form the subject matter for the ten papers in this section, and included are such titles as—Some application of the X-ray powder methods in industrial laboratory problems, an X-ray examination of mechanical wear products and some examples of industrial testing of materials by X-ray diffraction. The second part of the symposium is planned to be published in the July issue.

(Abstract supplied by Research Dept. Met. Vick.)

Least Work Solution of Shear Lag Problems. (E. Reissner, J. Aeron. Sci., Vol. 8, No. 7, May, 1941, pp. 284-291.) (91/41 U.S.A.)

The problem of the distribution of stresses in the cover sheets of box-beams, acted upon by bending loads, is treated by assuming parabolic bending stress distributions across the sheets and by determining the spanwise variation of the shape of these paraboles with the help of the method of least work (Castigliano's principle). A second order differential is obtained for the spanwise variation of the vertex curvature of the stress parabolas (which in the ordinary beam theory are straight lines). The equation has constant coefficients if there is no taper in sheet width and thickness, variable coefficients for tapered sheets. The equation is found to be integrable in terms of elementary functions for untapered beams and for a rather general class of tapered beams. The solution for beams of constant cross-section is worked out explicitly and applied to the analysis of a series of beams having different load distributions. For beams of constant cross-section an approximate formula is developed for the amount of shear lag at the most highly stressed section, this being in general also the section of greatest shear lag. This formula depends on the ratio of sheet width and distance of the centre of gravity of the load curve from the root section, on the elastic moduli and on the relative stiffness of flanges and sheets. Further it is shown that a design is possible such that no shear lag occurs. The method developed, and extensions of it, should permit a relatively simple solution for most practical problems in this field of stress analysis.

Harvey Directional Control. (Inter. Avia., No. 753, 6/3/41, p. 6.) (91/42 U.S.A.)

A promising direction-finding instrument has been developed by the Harvey Machine Co., Los Angeles, Calif. The Harvey Directional Automatic Radio Control fully automatically flies an aeroplane along a straight-line course passing through two radio stations, the manufacturers guaranteeing an accuracy to within one degree at any point of the course, regardless of meteorological conditions. The range of the equipment is said to exceed 1,000 miles. The new Harvey instrument consists of a combination of two independent homing devices, the signals of which are opposed to each other. As long as the aircraft is on course, the difference between the two angles formed by the intersection of the plane's longitudinal axis with the line of the course will be zero, no matter how the machine may be headed to correct for wind drift. As soon as the aircraft departs from true course these angles are no longer equal and the signal of one

station will overbalance the other. By means of an amplification system these signals operate a servo motor actuating the directional rudder control; hunting along the course is avoided by making the amplification inversely proportional to the signal strength. The equipment weighs 60 lb.

Devices for Locating Airliners on Their Respective Courses. (Inter. Avia., No. 753, 6/3/41, p. 15.) (91/43 U.S.A.)

At about the same time two of the big American airlines, United Air Lines and Transcontinental and Western Air, announced new devices for the automatic supervision of the location of the airliners on their respective courses. The device of T.W.A. is very simple and consists for each schedule of a small aircraft model moving along an electrically operated worm at a speed regulated according to the pilot's flight plan. The main advantage of the invention is that the dispatching office is automatically warned by an alarm signal in case an aircraft passes over one of the check points along its course without making its radio report. Of much greater interest and representing much more than a technical plaything is the invention of United Air Lines. Without the aid of the pilot and even without his knowledge the location of every aircraft is determined by several ground stations taking bearings on the machine as soon as the crew gets into short-wave radio telephone communication with any ground station. The installation makes it possible to inform the ground personnel of any deviation from the true course and to warn the pilot accordingly.

Photo-Electric Humidity Measurement. (C. Strobel, E.T.Z., 6/6/40, pp. 515-518.) (91/44 Great Britain.)

The author describes a new photo-electric method of measuring the dew point, and permitting of exact measurement of the humidity in the air and other gases within the temperature range of -10 to $+250$°C. He also gives an electric circuit which, without the use of vapour pressure or psychrometer charts, makes possible direct and linear indication of the relative humidity as a percentage on an electrical pointer instrument or recording apparatus.

(Abstract supplied by Research Dept. Met. Vick.)

Flight Level Indicator. (R. W. Knight, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, pp. 242-245.) (91/45 U.S.A.)

1. Flight level indicators, uniformly measuring pressure altitudes above a non-adjustable base, provide a solution to the universal problem of maintaining cruising and holding altitudes.

2. Relating flight levels to compass directions assures maximum vertical distance between aeroplanes on intersecting courses.

3. Relating flight levels to compass directions provides a simple easy rule for pilots to follow.

4. The use of this instrument would permit great simplification of air traffic rules. Fewer and simpler rules mean less violation and greater safety.

5. The absence of any adjustments eliminates the possibility of incorrect settings.

6. Even though all pilots do not maintain the pointer in exact agreement with the magnetic compass, the danger of collisions will be substantially reduced.

7. While the flight level indicator may be used to check the altimeter it does not take the place of the altimeter. The function of the altimeter is the maintenance of terrain clearance, while that of the flight level indicator is the maintenance of interplane clearance.

8. The cost of such instruments built in volume would be relatively low.

9. The weight of 1.17 pounds and space occupied in the instrument panel are justified.

10. The flight level indicator may be used in connection with the autopilot as a means of automatically controlling cruising altitudes.

An Electro-Optic Pressure Indicator. (Robertson, Rev. Sci. Instr., March, 1941, pp. 142-148.) (91/46 Great Britain.)

The author describes improvements on a diaphragm type of engine pressure indicator. The indicator takes advantage of the fact that a polished metal diaphragm forming part of the combustion chamber wall will be deflected in the form of a spherical mirror when there is a pressure difference across it. The intensity of a beam reflected from this diaphragm will vary with the pressure and by measuring the changes in intensity of the beam an indication of the change of engine pressure is obtained. It is stated that the indicator may be used at any engine speed and that a special direct-current amplifier has been constructed for this purpose.

(Abstract supplied by Research Dept. Met. Vick.)

A Ballistic Meter for Measuring Time and Speed. (Reich, Toomim, Rev. Sci. Instr., Feb., 1941, pp. 96-99.) (91/47 Great Britain.)

This paper describes a speedmeter in which a ballistic galvanometer serves as the indicating and recording element. Current flow through the galvanometer is initiated and stopped by means of a thyratron controlled by two switches. It is stated that the instrument was designed primarily for the measurement of automobile speeds in traffic studies, and should have other applications.

(Abstract supplied by Research Dept. Met. Vick.)

Night Photography by Means of Mg. Flare. (Inter. Avia., No. 752, 27/2/41, p. 11.) (91/48 U.S.A.)

The possibility of taking perfect photographs at night by means of extremely powerful flares is described as a new, very effective weapon adopted by the U.S. Army Air Corps. The method has been developed by Major G. W. Goddard in co-operation with the Eastman Kodak Co. and consists mainly of heavy, cylindrical flares about 32 in. high and 7 in. in diameter which are dropped without parachute. Following its release the flare is fired automatically and the magnesium content burns up in an explosion, developing a flash of several million candlepower. The combustion is completed within one-sixth of a second, during which period an area of about 19 sq. miles can be sufficiently illuminated. The shutter of the camera is operated via a relay by a photo-electric cell activated by the explosion of the flare; the negative (8 by 10 in.) is exposed at the peak of the flash which is attained 1/5,000 of a second after the explosion. The period of illumination, which lasts only a fraction of a second, and the strong blinding effect of the flare is said to prevent the betrayal of the position of the reconnaissance aeroplane.

Influence of War Experiences on the Development of A.R.P. Lighting. (E. Kämmerer, E.T.Z., 13/6/40, pp. 537-541.) (91/49 Great Britain.)

The author discusses black-out measures for work-rooms under the following sub-headings: (a) mechanical black-out; (b) paritally mechanical black-out in conjunction with technical lighting measures; (c) partially mechanical black-out in conjunction with brushing paints which are impervious to light; (d) suppression filter method as black-out (complimentary colours); (e) technical lighting measures; (f) luminous substances. In conclusion the question of external lighting is discussed.

(Abstract supplied by Research Dept. Met. Vick.)

A Study of the Development of Skill During Performance of a Factory Operation. (R. M. Barnes and J. S. Perkins, Trans. A.S.M.E., Vol. 63, No. 4, May, 1941, pp. 319-328.) (91/50 U.S.A.)

While in general the many studies into the nature of skill have been concerned with the total time required to accomplish a given task and the influence on time values of varying conditions pertaining to a specific operation, this paper

is primarily devoted to a time study of the elements entering into the performance of an industrial task. The investigation constitutes a pioneer effort to study the effect of practice on a typical factory operation, conducted under laboratory conditions.

The various aspects of the study on which information was sought are as follows:—

1. The effect of practice on a typical factory operation carried on under laboratory conditions.
2. The learning curves of the various elements of the operation as they were performed by each of the different subjects.
3. The consistency between subjects in learning the same element.
4. The effects of " speeding."
5. The dispersion and its relation to the average performance time.
6. The effects of fumbling on the normal learning curve.
7. The several ways in which a transport load and pre-position element was performed.
8. The effectiveness of several rating techniques on data of known quality.
9. The effect of practice on the relation of eye movements to hand motion.

Summing up the discussion the paper seems to prove the desirability of establishing time standards from data as compared with individual time studies; and indicates that jobs should be planned to avoid, as much as possible, conditions which might cause fumbles. Two-thirds of the improvement noted was in the elimination of fumbling and one-third was due to faster movements and better co-ordination.

On the Technique of Forecasting Low Ceiling and Fog. (J. J. George, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, pp. 236-241.) (91/51 U.S.A.)

As far as the formation of fog is concerned, air loses its maritime properties on being exposed to sunshine over land for only a few hours. Accordingly fog which forms over land may be called " radiation " when the trajectory of the air has been mostly continental, and " advection " when it has not been over land during the day preceding the formation of the fog. It is found that radiation fog forms only when the air has been under a cloud cover a part of the previous day, and a forecasting method for such formations is developed. The forecasting of advection fog is shown to be more complex, and various methods necessary in such work are discussed. Examples of each type are presented.

An analysis of the causes of errors being made at present in the forecasting of fog and low ceilings is made, and indicates that substantial improvement in short range forecasts of such conditions is possible at this time. Suggestions for the elimination of present faults are made and a systematic method of forecasting described.

Examples and Outline of Certain Modifications in Upper Air Analysis. (R. B. Montgomery and A. T. Spilhaus, J. Aeron. Sci., Vol. 8, No. 7, May, 1941, pp. 276-283.) (91/53 U.S.A.)

The first part of this paper deals with methods of isentropic analysis based on the scaled values of data transmitted for the purpose by the United States Weather Bureau. The practical application of shear-stability ratio vectors is demonstrated. A logical order of analysis is presented, designed to make the fullest possible use of all data available. The preferred isopleths for direct representation are those of temperature, acceleration potential and specific humidity; a system of isopleth spacing convenient in conjunction with surface weather maps is employed.

In the second part the properties of various surfaces for upper air analysis are systematically studied. It is found that severe restrictions exist in the use of surfaces of constant entropy or potential temperature. All the properties dis-

cussed are, however, adequately satisfied by a surface of constant potential virtual temperature, a quantity newly introduced and defined as the potential temperature of matter of standard composition, in this case dry air, at the same pressure and density as the sample. The thermodynamic configuration of this surface is described by isotherms of virtual temperature.

Infra-Red Radiation. (Koller, G.E. Rev., March, 1941, pp. 167-173.) (91/52 Great Britain.)

This paper collects information on the production, transmission, reflection and measurement of infra-red radiation. The fundamental laws of radiation are outlined and detailed consideration is given to the various sources of infra-red and to the characteristics of the radiation when passing through different media. Mention is made of the several methods of detection and it is suggested that the high-vacuum thermopile and galvanometer is the most suitable for measuring infra-red radiation.

(Abstract supplied by Research Dept. Met. Vick.)

Pilot Balloons Made Out of Transparent Plastic Film. (K. Eisele, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 147-154.) (91/54 Germany.)

It has been noted that pilot balloons made of rubber and designed for really high altitudes (~40 km.) seldom pass 30 km. without bursting. The author considers that the main reason for this difficulty is the deterioration of the rubber at the low temperatures existing at these altitudes. Replacing rubber by a very thin transparent plastic has not been successful, as these synthetic substances become very brittle at low temperatures. The difficulty can be overcome by spraying the foil with a dark cellulose varnish, provided the thickness of the deposit is suitable (if the deposit is too thin, insufficient radiation is absorbed; if too thick the inner layers of the film are shielded). The film material used by the author has a cellulose base and is known under the trade name of Cuprophan. The thickness is .0065 mm. and its weight 10 gm./m.^{2}. It is obvious that the construction of a balloon made of such thin, and moreover inelestic material, presents considerable difficulties. Some of these, as well as the method of launching finally adopted, are described. Preliminary tests with balloons of this type have proved promising. Several larger designs were in hand when the advent of the present war stopped further experiments.

The Resistance Coefficient of Commercial Types of Wire Grids. (B. Eckert and F. Pfluger, L.F.F., Vol. 18, No. 4, 22/4/41, pp. 142-146.) (91/55 Germany.)

The grids examined were made of round wire varying between 0.1 and 0.7 mm. diameter with number of meches/cm. ranging from 1.5 to 63. The grids were supported in a tube of 45 cm. diameter and the resistance coefficient C_w determined from the equation

$$C_w = \Delta p / (\rho/2)\, V^2$$

when Δp = pressure drop across grid.
V = air speed at entry to grid.

The results are expressed in the form of graphs giving C_w as a function of air speed, Reynolds number and solidity (at constant Re) respectively. Solidity is defined as (projected area of wire)/(area of grid boundary). Maximum air speed (m./sec.) and Re were of the order of 30 and 1,000 respectively.

Under the conditions of the test (flow at entry mainly laminar) C_w undergoes a marked diminution with increase in air speed between 2 and 100 m. per sec. At higher speeds C_w is practically constant.

From the data provided it is easy to construct wire grids having a given resistance coefficient for a certain grid boundary area. In conclusion, the authors attempt to obtain theoretical values of C_w and with the help of certain assumptions, agreement with experimental values can be obtained.

LIST OF SELECTED TRANSLATIONS.

No. 34.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft Production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

MATERIALS.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND REFERENCE.
1188	Kotzochke, P. ...	*Materials and Design Features of Captured (i.e., non-German) Aero Engines.* (Luftwissen, Vol. 8, No. 3, March, 1941, pp. 69-78.)
1189	Cornelius, H. ...	*Investigations of Some Steel Fittings in Captured Non-German Aircraft.* (Luftwissen, Vol. 8, No. 3, March, 1941, pp. 78-81.)
1196	Hollbach 6	*Aircraft Materials.* (Deutscher Flugzeugbau (Handbook of the German Aircraft Industry), 1939, pp. 176-179.)
1200	Perkuhn	*Behaviour of Laminated Pressed Synthetic Resins Under Creep.* (L.F.F., Vol. 18, No. 1, 28/2/41, pp. 32-37.)

AIRCRAFT AND ACCESSORIES.

1191	——	*D.F.S. Two-Seater High Performance Sail Plane Kranich for High Altitude Flight.* (Flugsport, Vol. 30, No. 19, 14/9/38, pp. 49-50.)
1192	——	(*E.W.2*) *Four-Seater Sail Plane* 108-116. (Flugsport, Vol. 32, No. 4, 14/2/40, pp. 51-54.)
1193	Hollbach 6	*Safety Devices.* (Deutscher Flugzeugbau (Handbook of the German Aircraft Industry), 1939, pp. 111-116.)

INSTRUMENTS.

1194	Hollbach 6	*Meteorological Instruments.* (Deutscher Flugzeugbau) (Handbook of the German Aircraft Industry), 1939, pp. 117-122.)
1195	Hollbach 6	*Flight Instruments.* (Deutscher Flugzeugbau) (Handbook of the German Aircraft Industry), 1939, pp. 117-122.)

MISCELLANEOUS.

1201	Wieghardt, K. ...	*Comprehensive Survey of Research on the Statistical Theory of Turbulence.* (L.F.F., Vol. 18, No. 1, 28/2/41, pp. 1-7.)
1205	Beringer, A. ...	*A Mechanical Method for Blacking-out Large Factory Skylights.* (V.D.I. Zeitschrift, Vol. 85, No. 13, 29/3/41, p. 306.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING MAY, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

THEORY AND PRACTICE OF WARFARE.

76/1	Germany ...	*Air Force Targets in Germany: No. 18 Bremen.* (Engineer, Vol. 171, No. 4,444, 14/3/41, pp. 179-180.)
76/2	Great Britain	*Sound Detector for Roof Spotting.* (Engineer, Vol. 171, No. 4,444, 14/3/41, p. 184.)
76/3	Germany ...	*Focke-Wulf F. W. 187 Zerstorer (Two-Seat Fighter).* (Flight, Vol. 39, No. 1,680, 6/3/41, p. 187.)
76/4	Great Britain	*Blackburn "Skua" and Junkers Ju 87. Comparison of External Appearance.* (Flight, Vol. 39, No. 1,680, 6/3/41, p. a.)
76/5	U.S.A. ...	*Douglas "Boston" Attack Bomber.* (Flight, Vol. 39, No. 1,680, 6/3/41, pp. f-h.)
76/6	Japan ...	*Japan's Air Strength.* (Aeroplane, Vol. 60, No. 1,554, 7/3/41, pp. 280-284.)
76/7	Italy ...	*Caproni Ca 133 Colonial Bomber.* (Aeroplane, Vol. 60, No. 1,554, 7/3/41, p. 286.)
76/8	U.S.A. ...	*Details of Current U.S.A. Military Aircraft Types and Table of Specifications.* (Aviation, Vol. 40, No. 2, Feb., 1941, pp. 76-95, 115-116.)
76/9	U.S.A. ...	*Design Details of American Aircraft (Sketches).* (Aviation, Vol. 40, No. 2, Feb., 1941, pp. 120-137.)
76/10	Great Britain	*Explosives: Lecture to Royal Institution, 11/2/41.* (G. I. Finch, Engineering, Vol. 151, No. 3,922, 7/3/41, pp. 214-215.)
76/11	U.S.A. ...	*New R.A.F. Types III. Curtis P-40A. Tomahawk Single-Seat Fighter Monoplane.* (Airc. Eng., Vol. 13, No. 145, March, 1941, pp. 60 and 67.)
76/12	Great Britain	*Training Types.* (M. de Bunsen, Aeronautics, Vol. 4, No. 2, March, 1941, pp. 38-40.)
76/13	Great Britain	*Mass Production of Military Aircraft.* (H. J. Wilson, Aeronautics, Vol. 4, No. 2, March, 1941, pp. 81-82.)
76/14	Great Britain	*New Tactics for New Aircraft.* (Aeronautics, Vol. 4, No. 2, March, 1941, pp. 55-56.)
76/15	Great Britain	*Shadow of Night Bomber. (Tables giving Hours of Darkness for Various Localities and Seasons.)* (N. McMillan, Aeronautics, Vol. 4, No. 2, March, 1941, pp. 58-61.)
76/16	Great Britain	*Notes on the Duties of the Air Council.* (J. M. Spaight, Aeronautics, Vol. 4, No. 2, March, 1941, pp. 74-78.)
76/17	U.S.A. ...	*American Help for Britain, Factory and Labour Organisation, etc.* (Inter. Avia., No. 746, 23/1/41, pp. 1-9.)

76/18 Germany ... *Focke-Wulf "Kurier" (Military Version of F.W. 200).* (Inter. Avia., No. 746, 23/1/41, p. 10.)

76/19 Great Britain *New British Equipment (Botha I, Spitfire III, Hawker Tornado, Short Stirling).* (Inter. Avia., No. 746, 23/1/41, p. 11.)

76/20 Great Britain *Fairey Fulmar Two-Seater Fighter.* (Inter. Avia., No. 746, 23/1/41, p. 12.)

76/21 U.S.A. ... *Douglas A-20A, Attack Bomber (R.A.F. "Boston") (Development of D-B7).* (Inter. Avia., No. 746, 23/1/41, p. 14.)

76/22 U.S.A. ... *Speed of American Fighters.* (Inter. Avia., No. 746, 23/1/41, pp. 14-15.)

76/23 Great Britain *Development of the Night Bomber During the Last 26 Years.* (Flight, Vol. 39, No. 1,683, 27/3/41, pp. a-g.)

76/24 Italy ... *Caproni Ca 310 Libeccio Reconnaissance Bomber.* (Aeroplane, Vol. 60, No. 1,556, 21/3/41, p. 336.)

76/25 U.S.A. ... *NA-40A Two-Motor Bomber.* (Aeroplane, Vol. 60, No. 1,556, 21/3/41, p. 338.)

76/26 U.S.A. ... *Arms and the American Aeroplane.* (G. Herrick, Aeroplane, Vol. 60, No. 1,556, 21/3/41, p. 338.)

76/27 Italy ... *Caproni Ca 311 Reconnaissance Bomber.* (Aeroplane, Vol. 60, No. 1,557, 28/3/41, p. 368.)

76/28 Great Britain *Repairs to Service Aircraft.* (G. H. G. Garbett, Aeroplane, Vol. 60, No. 1,557, 28/3/41, pp. 370-372.)

76/29 Italy ... *The Ghost of General Douhet.* (By Caldwell, Aero Digest, Vol. 38, No. 2, Feb., 1941, pp. 43-48 and 196.)

76/30 U.S.A. ... *Consolidated "Liberator" Heavy Bomber.* (Engineer, Vol. 171, No. 4,446, 28/3/41, p. 216.)

76/31 Great Britain *The Hawker Hurricane—Production Methods.* (W. E. Goff, Airc. Prod., Vol. 3, No. 30, April, 1941, pp. 126-134.)

76/32 Great Britain *High Speed Fire Alarm for Detecting Incendiary Bombs.* (The Engineer, Vol. 171, No. 4,447, 4/4/41, p. 225.)

76/33 Great Britain *Machining of H.E. Shells (Note).* (The Engineer, Vol. 171, No. 4,447, 4/4/41, p. 227.)

76/34 Great Britain *Fire Protection of Structural Steelwork: Wartime Building Bulletin No. 13.* (D.S.I.R., London: Stationery Office, 1/-.) (Engineer, Vol. 171, No. 4,447, 4/4/41, p. 229.)

76/35 U.S.S.R. ... *On the Transmission of Detonation from Cases to Explosives.* (J. B. Chariton and E. V. Rdultovskaja, Compt. Rend. Acad. Sci., U.S.S.R., Vol. 23, No. 6, 1939, pp. 530-531.) (Abstract available.)

76/36 U.S.S.R. ... *On the Transition of the Combustion of Explosives into Detonation.* (J. B. Chariton and B. M. Stapanov, Compt. Rend. Acad. Sci., U.S.S.R., Vol. 23, No. 6, 1939, pp. 527-529.) (Abstract available.)

76/37 U.S.A. ... *Curtiss Tomahawks (Sectional Drawing).* (Flight, Vol. 39, No. 1,682, 20/3/41, p. 224.)

76/38 Great Britain *The Slip Wing Bomber (A Reply to Criticism).* (N. Pemberton Billing, Flight, Vol. 39, No. 1,682, 20/3/41, pp. 225-226.)

76/39 U.S.A. ... *Revelations of "Secrets." (Notes on American Aircraft from Model Airplane News, and Flying and Popular Aviation, Feb., 1941.)* (Aeroplane, Vol. 60, No. 1,555, 14/3/41, pp. 305-307.)

76/40 Italy ... *Caproni Ca 135 bis Bomber.* (Aeroplane, Vol. 60, No. 1,555, 14/3/41, p. 308.)

76/41 Germany ... *The Focke-Wulf Kurier Fw 200K.* (Aeroplane, Vol. 60, No. 1,555, 14/3/41, p. 310.)

76/42 U.S.A. ... *Photographs and Simplified Data of Renamed American Types in the R.A.F.* (Flight, Vol. 39, No. 1,681, 13/3/41, pp. b-g.)

76/43 Germany ... *The September Attacks on British Military Objectives.* (Luftwissen, Vol. 7, No. 10, Oct., 1940, pp. 333-337.)

76/44 Germany ... *E. Zindel, The Designer of Ju. 52 and Ju. 88.* (Luftwissen, Vol. 7, No. 10, Oct., 1940, p. 358.)

76/45 Germany ... *The Influence of the Power Plant on the Design of the Aircraft Structure.* (Luftwissen, Vol. 7, No. 10, Oct., 1940, pp. 355-357.)

76/46 Germany ... *Air Academy Gatow (Staff College) Five Years Old.* (Luftwissen, Vol. 7, No. 10, Oct., 1940, p. 358.)

76/47 Germany ... *Dornier Do. 172. Refuelling (Photograph).* (Aeroplane, Vol. 60, No. 1,559, 11/4/41, p. 407.)

76/48 Germany ... *Ground Hot Air Heater for Do. 215 (Photograph).* (Aeroplane, Vol. 60, No. 1,559, 11/4/41, p. 408.)

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ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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(Prepared by R.T.P.)

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Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automobile Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.

J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Veroffentlichungen aus dem Gebiete der Nachrichtentechnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

German Air Raid Defence of Factories. (C. Wachtel, Chemical and Metallurgical Engineering, Vol. 48, No. 4, April, 1941, pp. 92-94.) (92/1 U.S.A.)

It is stated that the author was formerly director of the German Institute of Industrial Hygiene and had been employed by the German and Russian Governments as an expert on the defence of factories against aircraft. Methods of passive defence have formed the subject of serious study on the continent for a number of years. The position of a factory is largely determined by economic conditions (facilities of providing labour and materials, road and rail connections, etc.). No position can be regarded as outside the range of modern aircraft and therefore immune from attack. Decentralisation reduces the risk but slows up production. Much can be done in the proper lay-out of the plant (so-called ribbon arrangement making the fullest use of natural camouflage, such as trees, etc.). Framed structures are generally best and the roof should be sufficiently strong to stop incendiaries. Unfortunately the precautions to be adopted differ radically, depending on whether the bomb explodes inside or outside the building. In the former case, light walls and floors will localise the damage. Heavy walls and roofs are required to withstand blast due to a near miss. The relative risk must therefore be apportioned.

Vital sections of a factory must be placed underground. The same applies to vital stores of fuel, material and finished products. It is stated that such underground storage has been extensively adopted in Germany, by the full utilisation of existing facilities, such as wine and beer cellars, etc., the use of natural cavities such as occur in salt mines, etc., and by the provision of new underground structures. Alternative sources of supply of electric power, water and gas must be available. The same applies to telephone circuits. The author states that Fifth Column activities always present a possible source of danger. This can best be guarded against by harmonious labour conditions, ensuring solidarity between employer and employee. In this case, every member of the staff becomes an alert guard against all types of sabotage.

Atlantic Ferry, U.S.A.-Great Britain. (Inter. Avia., No. 763, 9/5/41, pp. 6-7.) (92/2 U.S.A.)

According to American sources, the possibility of flying medium bombers from Canada to Great Britain was already investigated during the autumn of last year, when experiments were started with the Lockheed Hudson. This aircraft, under normal conditions, has an endurance of ten hours at cruising speed (170 m.p.h.). As a tail wind of 20 m.p.h. can be reckoned on with certainty, the trip should average 11 hours, and with a 33 per cent. margin, a total fuel capacity of 1,200 U.S. gallons and 60 gallons of oil was calculated (2 radial engines rated at 1,100 h.p. each). As the normal useful load of this aircraft is only 6,100 lbs. (normal gross weight 17,000 lbs.), this means an overload of about 2,300 lbs., the wing loading increasing from 31 to 36 lbs. sq. ft. The extra fuel (app. 400 gallons), is stored in flexible rubber tanks, which drain into the main tank and can be discarded when empty. The start is usually made just before dusk and the landing by daylight next morning. Enemy interference is thus out of the question and no armament is carried. A similar procedure has been applied to other medium bombers (Ventura and Maryland), of normal gross weights of 18,500 and 15,300 lbs. respectively. The cruising speed of these machines (with 20 m.p.h. tail wind) is of the order of 220 m.p.h., and the overload required is of the order 2,200 and 3,000 lbs. respectively.

It appears that the larger bombers, such as the Catalina (normal gross weight 30,500 lbs.), and Liberator (normal gross weight 41,000 lbs.), can carry enough fuel for the trip without overloading the machines.

The delivery of fighters in the north of Scotland from Labrador with the help of intermediate stops in Greenland and Iceland, is under consideration. Since no radio help can be expected, the navigation may present difficulties.

Nylon Fibre for the Air Force. (Inter. Avia., No. 760, 16/4/41, p. 9.) (92/3 U.S.A.)

Fabrics manufactured of Nylon artificial fibre, a coal derivative developed by the American chemical concern, E.I. du Pont de Nemours, has been tested over a considerable period by the U.S. Army's Material Division at Wright Field, and compared with pure silk, as a possible substitute for the latter, for use in the manufacture of parachutes. It was found that Nylon Fabrics suffered a greater loss in strength under the effect of ultra-violet rays than silk; however, the tensile strength of Nylon decreased only one-tenth after twenty days of continuous exposure to snow, rain and sunshine, while silk decreased one-third. Exposure to 170 hours of strong sunlight resulted in silk losing 61 per cent. of its tensile strength, while Nylon lost 67 per cent. Since, however, the original tensile strength of the synthetic fabric was considerably greater than silk, and the loss in elasticity under meteorological influences was smaller, the Nylon fibre appears to be at least equally suitable for the manufacture of parachutes as pure silk.

U.S.A. Type Designation. (Inter. Avia., No. 762, 1/5/41, p. 10.) (92/4 U.S.A.)

As is known, the aircraft types ordered by the U.S. Army Air Corps are not designated according to the same methods as those of the U.S. naval air service. The *Army designations* contain a letter marking the class of aircraft, such as " B " for bomber, " P " for pursuits, meaning fighters or interceptors, " PT " for primary trainers, " AT " for advanced trainers, " BC " for basic combat trainers, etc. The figure following this letter designates how many types of this class of aircraft have entered the Air Corps and are given to the new aeroplanes independently of the manufacturers' designation. The designation P-40D indicates, therefore, that the machine is the 40th fighter type of the U.S. Army Air Corps and the fourth version of the prototype P-40. The custom to precede the designation by the letter " X " for the experimental or prototype, and the letter " Y " for the aircraft of the first trial series, is well known, and is employed both by the U.S. Army and Navy. The *type designations of the Navy* are not so clear at a glance because details of the manufacturing company are added to the class designation. The figure preceding the letter denoting the manufacture, indicates how many types of the same aircraft class the manufacturer in question has supplied to the Navy, and the last figure refers to modified versions of the prototype. The designation XSB2C-1, much mentioned in the past few weeks, stands for: Prototype (X) of the second scout bomber (SB2) supplied to the Navy by the Curtiss company (C). Any later version of the same type will be given the designation SB2C-2. Not all manufacturing companies have been assigned a letter corresponding to their own initials; this is due to the fact that the respective letters are reserved to that company of several with the same initial which was the first to supply aircraft to the Navy. From this, certain misunderstandings may result, and therefore the identification letters of the main suppliers are given below in alphabetical order: A for Brewster, B for Boeing, C for Curtiss, D for Douglas, F for Grumman, L for Bell, M for Martin, U for Vought-Sikorsky, and Y for Consolidated.

New Military Types of the R.A.F. and Luftwaffe for 1941. (P. Dublanc, La Science et la Vie, Vol. 59, No. 286, June, 1941, pp. 457-465.) (92/5 France.)

The following types are briefly described.

R.A.F.: Typhoon, Tornado, Whirlwind, Beaufort, Beaufighter, Manchester, Stirling, Fulmar, Botha.

Germany: FW 187 and 189.
Me 115.
He 119.

The Focke-Wulf FW 187 " Destroyer " is an improvement on the Me 110 twin engined fighter. The dimensions of the central fuselage have been reduced by placing the two members of the crew in line instead of side by side. The front seat is occupied by the pilot, a window in the floor of the nose ensuring good ground view. The central fuselage also carries the six fixed guns (two 20 m/m. cannons on the floor and four machine guns, two a side), whilst the nose is armour plated. The charging and maintenance of these guns is carried out by the second member of the crew. The rear gun of the Me 110 has been suppressed. Two DB603 engines are fitted, rated at 1,600 h.p. each.

The FW 189 is a short range reconnaissance machine (3 seater), fitted with two Argus 12 cylinder V air-cooled engines rated at 500 h.p. each. The nacelles are continued towards the rear to carry the tail unit, the machine thus being of the twin fuselage type. The central cabin is amply provided with windows to ensure exceptional visibility. A top speed of over 300 m.p.h. is claimed. The new single seat fighter *Me* 115 has a slightly smaller wing span than the Me 109

(9.5 m. instead of 10 m.). The main difference is in the power plant, the DB603 engine being rated at 1,600 h.p. against the 1,100 h.p. of the earlier DB601 model. A top speed of 640 Km./h. is claimed.

The Heinkel He 119 twin engined bomber has been specially designed to take advantage of the new DB605 engine rated at 2,100 h.p. (24 cylinders). It is not certain whether this power plant is an X engine (2 DB 601), or whether two 2 DB 601 are placed in line, driving contra propellers similar to the Fiat project. It is stated that a bomb load of over three tons can be carried.

The Rôle of the Air Force in the Battle of the Ionian Islands (27-29 *March*) (C. Rougeron, La Science et la Vie, Vol. 59, No. 286, June, 1941, pp. 466-480.) (92/6 France.)

This naval engagement is of special interest, since for the first time, both fleets were provided with reconnaissance and bomber aircraft. Although the Italian ships were more modern and of much higher speed, their weaker armour proved very vulnerable to air attack. It appears that even bombs exploding in the water at some distance distorted the hulls of the Italian vessels to such an extent, that the designed speeds could no longer be maintained. After a chase of some hours, the slower British vessels were able to catch up and with their heavier guns and armour, easily disposed of the enemy. According to the French author, the sacrifice of hull strength for speed is thus very dangerous, for the surface speed of the boat will always remain very much below that of pursuing aircraft, and even the strongest anti-aircraft defence cannot prevent some bombs exploding in the neighbourhood of the hull. Unless therefore, the possibility of aircraft attack can be ruled out, there is no object in designing warships primarily for speed, *i.e.*, at the sacrifice of adequate armour plating of the hull. Aerial attack is likely to be most effective if the aircraft can make use of shore bases, and the author is of the opinion that only very heavily armoured ships should venture into the effective range of such stations.

Emergency Evacuation of Fuel Tanks on Dive Bombers. (La Science et la Vie, Vol. 59, No. 286, June, 1941, p. 517.) (92/7 Germany.)

Dive bombers are liable to forced landings without the pilot having a chance of using his parachute. Such landings, being necessitated by structural damage of the machine by A.A. fire, are likely to be very rough, and the chance of the machine catching fire are correspondingly great. For this reason, the German Ju 88 dive bombers are provided with means for a rapid evacuation of the fuel tank. For this purpose, the tank is provided with a vertical stand pipe reaching almost to the bottom, the upper portion of the tube being continued to the tail of the machine. A control in the pilot's cockpit enables him to subject the petrol to the pressure of the engine superchargers, with the result that the fuel is ejected very quickly.

The Use of Dummies in the Camouflage of Operational Aerodromes. ((E. Z. Yasin, Air Fleet News, U.S.S.R., Vol. 23, No. 5, pp. 423-429.) (92/8 U.S.S.R.)

Dummy figures, buildings, etc., not only permit of masking the presence of aircraft and equipment on the aerodrome, but are also useful to give the field the appearance of being unsuitable for use by aircraft.

Such dummies, *i.e.* mock-ups of the usual local features of the landscape, should be capable of simple construction with the materials to be found on the site, and easily removable, in order not to interfere with the operation of the aerodrome.

Owing to the possibility of discovery by means of stereo-photography, three-dimensional dummies (mock-ups) are usually more suitable than two-dimensional, flat camouflage, although the latter is useful to indicate surface features—roads, paths, ditches, etc.

The preparation of standard camouflage dummies in advance, as part of the operational equipment, is undesirable, as absorbing additional transport, furthermore, standardised dummies will not always match the locality.

Dummy aircraft, which could well be factory produced, appear very effective. They should, however, always be camouflaged themselves, to heighten the deception, and allay suspicions as to their genuineness.

Dummy trees are useful in conjunction with existing woodland or groups of natural trees. Suggestions on their construction and use are given.

Dummy buildings should always conform to the type and style current in the locality. They can be used to mask the presence of aircraft and equipment, as well as to change the appearance of the aerodrome. They should be simply constructed, of local materials, and easily removed.

Dummy groups of animals are particularly suitable for masking the character of the aerodrome. They can be used on runways, and quickly removed in case of need. It is sufficient for the dummy to represent roughly the outlines of the animal as seen from the air, and extreme adherence to detail should be avoided. Data on the necessary materials and labour are furnished.

Stacks and ricks are extremely suitable as dummies.

Flat two-dimensional camouflage to indicate cultivated ground, roads, etc. is very suitable for combined use with the foregoing. It can be made to remain in place when runways are in use, and is usually not worth retaining for re-use on another site; it should, therefore, be of the simplest and lightest materials.

Sketches and photographs illustrate the proposals made in the text.

Oxygen Equipment of German Aircraft. (N. P. Egorov, Air Fleet News, U.S.S.R., Vol. 23, No. 5, pp. 448-455.) (92/9 U.S.S.R.)

The article describes the "Auer A-824" type of oxygen apparatus which is standard for the Luftwaffe. A preliminary sketch of the systems of charging the oxygen cylinders in the aircraft—directly, from a mobile charging unit (preferred by the Luftwaffe), or from a stationary charging unit on the aerodrome. A description is given of the oxygen pumps employed for both methods.

After a detailed description of the "A-842" oxygen apparatus and its mode of operation, the conclusion is reached that the sole disadvantage is the necessity for manual operation of the valve for the supplementary airfeed.

Progress and Prospect in Aircraft Production in the U.S.A. (J. H. Jouett, President, Aeronautical Chamber of Commerce, Aut. Ind., Vol. 84, No. 10, 15/5/41, p. 515.) (92/10 U.S.A.)

U.S.A. aircraft manufacturers to date have been asked to build about 44,000 military aircraft, roughly distributed as follows:—

16,500	U.S.A. Army
8,500	U.S.A. Navy
16,000	Great Britain and Canada
3,600	bombers (Knudsen Plan)

The bulk of these orders have been placed since the autumn of 1940, and 7,000 'planes have so far been delivered. Since the outbreak of the War, 3,500 military aircraft have been supplied to Great Britain. The following production figures are quoted:—

November 1940	700	'planes	
December 1940	800	,,	
January 1941	1,000	,,	
March 1941	1,200	,,	
Summer 1942	2,400	,,	(estimated)
Total estimated output 1941	18,000	,,	
,, ,, ,, 1942	30,000	,,	

It is stated that a medium bomber consists of 30,000 parts, exclusive of bolts, nuts and rivets. These parts are worked into 650 sub-assemblies and these in turn into 32 major sub-assemblies, before the aircraft is finally assembled. The total labour involved amounts to 30,000 man hours per machine. The author concludes that even now, half the U.S.A. output, coupled with the British output, exceeds the Axis production.

Recent Air Corps Developments in Rotating Wing Aircraft. (H. F. Gregory, J. Aeron. Sci., Vol. 8, No. 8, June, 1941, pp. 331-333.) (92/11 U.S.A.)

The YG-1B Autogiro was not found suitable for needs of Army co-operation because of:

1. Tricky handling characteristics.
2. Insufficient landing and take-off performance.
3. Excess pilot fatigue.
4. Insufficient load carrying capacity.

The recommendations as a result of these tests were:

1. Development of high-performance low-speed airplane.
2. Improved performance of the autogiro.

The Air Corps developed the high-performance low-speed airplane known as the O-49, YO-50 and YO-51. It also carried on developments in the nature of improvements of theYG-1B Autogiro. These improvements covered the following features:

(*a*) Constant Centre of Pressure Rotor Blades.
(*b*) Accelerated Take-off Mechanism.
(*c*) Improved Rotor Starter.
(*d*) Direct Take-off.
(*e*) Flexible Pylon Mount.
(*f*) Installation of Larger Engine and Constant-Speed Controllable-Pitch Propeller.
(*g*) Flexible Landing Gear.

An aerodynamic investigation of a feathering control system is under way. So far, control of Army autogiros has been effected by tilting of the rotating mass. The feathering control system will vary the pitch of the blade cyclically for control. Ease of control, lessening of pilot fatigue, and improvement of vibration characteristics are expected.

The Air Corps is also engaged in the development of the helicopter. It is reasonable to predict a promising future for this type of craft.

The Use of A.A. Artillery in Aerial Warfare. (A. Fournier, La Science et la Vie, Vol. 59, No. 286, June, 1941, pp. 498-507.) (92/12 Germany.)

Experience has shown that aircraft operating at altitudes of the order of 6,000 m. is practically immune to A.A. fire of the heaviest calibre (88 or 94 mm.). Even if the calibre is pushed to 150 mm., the bomber need only rise to 8,000 m. in order once more to be practically safe. This applies in the daytime, when the predictor gear can be operated visually under optimum conditions. At night time when only sound detectors can be used, A.A. fire at these altitudes simply means a waste of ammunition. According to the author, the mere pressure of

powerful A.A. batteries serves however a useful purpose by reminding the adversary that a descent into lower altitude will be risky. Occasional bursts of fire is all that is required for this purpose. It produces the same results as a continuous barrage without the prohibitive cost in ammunition and wear of the guns.

Summing up, the author concludes that whilst the A.A. cannot prevent an attack, the chances of an important target surviving are considerably increased due to the inaccuracy necessarily associated with high altitude bombing.

Speed and Ceiling of Bombers. (C. Rougeron, Inter. Avia., No. 768-769, 16/6/41, pp. 1-4.) (92/13 France.)

Whilst the importance of high speed has been fully recognised for some time and adequately provided for by the designer of modern fighter aircraft, the corresponding advantages of a high ceiling are only lately receiving attention. This tardy development is partly due to the difficulty of ensuring adequate protection of the crew against the harmful effects of altitude. In the case of bombing aircraft it was moreover feared that the accuracy of bombardments carried out from altitudes in excess of 20,000 feet would suffer unduly. It must however be remembered that the high speed of modern aircraft has already affected the bombing from quite moderate altitudes and the increased ceiling will not make matters much worse. In any case, increased dispersion can be allowed for by proper choice of targets. The physiological effects of altitude on the crew can be kept within reasonable bounds by provision of pressure cabin or suits, combined with training and medical supervision. It appears that progress in the latter direction is most urgently wanted. In the author's opinion, the field of high altitude flying has been sadly neglected by the military authorities of all countries. The air force which will solve this problem first so as to operate effectively large formations at a greater altitude than the enemy will obviously have scored a great tactical advantage.

In the words of the author: "There is no lack of targets promising a sufficient efficacy of hits even from altitudes of 66,000 feet."

Visualised Aerodynamic Research by Means of a Smoke Tunnel. (R. W. Griswold, S.A.E. Journal, Vol. 48, No. 5, May, 1941, pp. 180-187.) (92/14 U.S.A.)

The tunnel is of the non-return-flow type, which design is dictated by the need for continuous supply of fresh air when smoke lines are injected into the flow. The test area, which is spanned by the model so as to give two-dimensional flow, has a high narrow rectangular cross-section. A heavy plate glass window is mounted flush with the internal surface in the front face of the tunnel to expose the model to view, with a field of 24 streamlines.

The power plant consists of a centrifugal blower, belt-driven from a model A Ford engine, with which combination air speeds up to 80 m.p.h can be attained. Exhaust heat from this engine is utilised to activate the smoke-supply apparatus. Smoke is generated by smouldering rotten wood in a special type stove.

With this equipment, a variety of model changes and modifications can be provided, the principal flow characteristics of which can be explored in a fraction of the time (and thus expense) and, in certain respects, more thoroughly than is normally the case for the less flexible three-dimensional quantitative tests. This tunnel is by no means a substitute for the latter equipment, but it already has proved to be a useful and convenient piece of supplementary equipment for preliminary and exploratory flow research concerned with aerodynamic problems susceptible to two-dimensional investigation. Photographic reproductions of a large number of typical flow patterns are given.

Note on the Method of Successive Approximations for the Solution of the Boundary Layer Equations. (J. H. Preston, Phil. Mag., Vol. 31, No. 209, June, 1941, pp. 452-465.) (92/15 Great Britain.)

A method of successive approximations was developed for the flow past a flat plate at high Reynolds numbers by Piercy and the present author in a previous paper. The first approximation corresponded to the asymptotic solution for Oseen's approximation, whilst the sixth was very close to the Blasius solution; thus in this case the convergence was satisfactory.

The method was generalised in a second paper by Piercy, Whitehead, and the present author. In this paper, solutions were restricted to cases where the pressures were those of the ordinary potential flow, or of a modified potential flow, obtained by introducing a crude representation of the wake.

The original purpose of the present note was to remove this restriction so that the method could be applied to cases where it was necessary to use experimental pressures.

Whilst satisfactory values of the skin friction may be expected in the region of accelerated flow for a limited number of approximations, it appears that in the retarded region, a large number of approximations will be required, and that even then a position of the breakaway may be uncertain.

The Elliptic Wing Based on the Potential Theory. (K. Kriens, Z.A.M.M., Vol. 20, No. 2, April, 1940.) (R.T.P. Translations T.M. 971.) (92/16 Germany.)

The present report deals with the elliptical wing in straight and angular flow on the basis of the potential theory. Conformably to the theory of first approximation upon which the calculation rests, the known requirements regarding the shape of the surface and its angle of attack must be met. A further condition is that the slope of the surface toward the streamlines must be a continuously differentiable function of the points of the surface. If this is not the case (for instance, by aileron deflection or wing dihedral—the latter being of importance in slideslips), the discontinuities must be replaced by suitable rounding off. In general, the calculation of a given elliptic surface requires a series of infinitely many potential functions, the co-efficients of which are afforded from linear infinite systems of equations. The expansion is stopped with a certain term, depending upon the degree of accuracy desired.

It may be mentioned that the computed potential and downwash functions change on transition to $K^2 \to 0$ (*i.e.* equality of elliptic axes), into Kinner's functions for the circular wing.

A large portion of the computations were made on the calculating machine, the accuracy of the slide rule being insufficient in the calculation of the elliptic integrals of higher order.

On the Subsonic Flow of a Compressible Fluid Past a Symmetrical Joukowski Aerofoil. (S. Tomotika and H. Umemoto, Aer. Res. Ints., Tokyo, Vol. 16, No. 205, March, 1941, pp. 35-125.) (92/17 Japan.)

In the present paper, the two-dimensional irrotional subsonic flow of a compressible fluid past a symmetrical Joukowski aerofoil placed at an arbitrary inclination to the direction of the undisturbed stream has been re-investigated in detail, with the special intention of studying the manner in which the value of the so-called critical Mach number for the symmetrical Joukowski aerofoil varies with the angle of attack as well as with the thickness ratio of the aerofoil.

The method first suggested by Poggi (1937) and subsequently described by Kaplan (N.A.C.A. Reports 621 to 671) has been employed. One of the interesting results obtained is that when the angle of attack takes any value different from

0°, the curve of the critical Mach number plotted against the thickness ratio t, has a maximum at a certain definite value of t. This feature seems to be worthy of special notice.

It is found that when the value of the angle of attack is fixed, the value of the ratio L_c/L_i for given symmetrical Joukowski aerofoil increases as the Mach number increases and also that the value of L_c/L_i for a definite Mach number increases slightly, with increasing angle of attack, where L_c denotes the lift which a symmetrical Joukowski aerofoil of a given thickness ratio experiences when placed in a stream of compressible fluid, and L_i the lift which the same aerofoil would experience when placed, at the same angle of attack as before, in the incompressible fluid flow.

In conclusion, the authors discuss briefly the validity of Glauert-Prandtl's approximate formula for the ratio L_c/L_i.

Supersonic Flow Studies. (T. Ackeret, Inter. Avia., No. 768-769, 16/6/41, pp. 9-10.) (92/18 Switzerland.)

Reference is made to experimental studies of supersonic flow carried out at the Swiss Federal Institute of Technology (Zurich). Striation photographs taken at M=.86 show separation of the boundary layer starting at about one third of the wing chord from the nose of a symmetrical aerofoil. This point is also marked by the presence of a small shock wave, inclined as usual towards the rear, the so-called Mach angle. The photographs are of special interest in showing the developments of a second shock wave of much greater intensity, emanating from the now separated boundary layer (at app. two-thirds chord), and spreading to a considerable distance at right angles to the wing on either side. The inclined shock wave, starting at the point of separation, meets this second wave, and direct measurement with a pitot tube shows that supersonic velocities are found throughout the triangular space so formed. Direct measurements also indicate that the wing surface pressure in the shock region is of the order of .6 adiabatic compression pressure. At this Mach Number (.86), the drag co-efficient of the aerofoil is about $7\frac{1}{2}$ times the normal (low speed) value, the first increase becoming marked at M=.75. Whilst very thin aerofoils delay this separation of the boundary layer to some extent, their employment meets with practical difficulties. The possibility of boundary layer control by suction is being investigated. If feasible, the drag increase normally associated with such high speed flight could be reduced.

The Nose Wheel Landing Gear. (Inter. Avia., No. 715, 24/4/41, pp. 1-5.) (92/19 Switzerland.)

The employment of landing flaps required the pilots to abandon their earlier landing techniques. The approach glide for the landing had now to be made with the longitudinal axis of the aircraft in a more or less forward-inclined position, and the change in the angle during flattening out, and stall was doubled. The logical thing was, therefore, to develop a landing gear in which the final position of the aeroplane on the ground corresponded more closely to the landing inclination. Thus, the way was paved for the nose-wheel landing gear, and to-day, practically all new commercial and military aircraft produced in the United States are fitted with the nose-wheel.

Since in the tricycle undercarriage the nose wheel is mounted far in front of the centre of gravity, the danger of a nose-over is completely eliminated, and full brake power can be applied immediately after touching down, as a result of which the approach glide for the landing need not necessarily be made at the minimum speed, and the dependency of the landing distance from the gliding speed is reduced. If a downward motion still exists upon touching down, it will not result in the aircraft jumping off again, no matter if the

nose-wheel or the main wheels touch down first, as on the one hand the location of the centre of gravity equally favours the touching down of all three wheels and, on the other hand, the wing has a smaller angle of incidence in the taxi-ing position than in the glide. Even when the tricycle aeroplane is flattened out at a great angle of incidence, the touching down of the main wheels immediately causes the nose-wheel to touch down also and, thus, a decrease of the angle of incidence. In drift landings or crosswind landings, the brake power of the main wheels creates a stabilizing moment which maintains the aeroplane's longitudinal axis in the landing direction, so that also in this case the danger of a lateral tip-over or a turning away from the landing direction is avoided.

Additional advantages of the nose wheel under-carriage are: Considerably improved vision for the pilot during take-off, landing and taxi-ing; simplified start, as the aeroplane already assumes the position offering the smallest frontal area, and the longitudinal axis of the aeroplane must not first be brought into the horizontal position by movements of the control column; finally, increased comfort for the passengers of commercial air-liners due to the fact that the longitudinal axis of the fuselage is practically constant during take-off and landing, and in level flight.

The main disadvantage of the nose wheel landing gear is an increase in the gross weight. This is explained by the fact that the main wheels must be designed for loads at least equal to those for which the main wheels of the conventional undercarriage are built. Even to-day, no generally valid load data for the calculation of the tricycle landing gear are available; in any case, however, the possibility of higher landing and taxi-ing speeds requires more rugged and therefore heavier designs. The major portion of the weight increase is furnished by the nose-wheel itself, which must be capable of withstanding the heavy loads resulting from the sudden braking of the main wheels, and must be connected with the rudder control. This requires a strengthening of the fuselage nose, which ultimately results in an increase of the weight of the entire tricycle installation by 50 per cent. over that of the tail-wheel landing gear.

It is quite possible that the universal adoption of the nose-wheel landing gear will profoundly affect the design of new types, inasmuch as it will be attempted to free the nose for the front wheel by shifting the power plant to the centre portion of the fuselage or by substituting pusher designs. It would appear that considerations of this kind have strongly influenced the development of the Bell P-39 " Airacobra " fighter, all the more as the unobstructed space in the fuselage nose was required also for the armament installation.

A disagreeable feature of the tricycle landing gear is formed by the shimmying tendency of the steerable nose wheel, discernible at certain speeds both at take-off and on landing.

Exhaustive tests conducted by the N.A.C.A. are ample proof that an improvement of these detrimental feaures is being sought. The main difficulty of the problem appears to lie in the fact that the nose-wheel shimmy should be eliminated without impairing the steerability of the wheel. Tests have shown that the effect of the type of tyre or tyre pressure is negligible, that the caster angle and spindle moment of inertia, influences the damping force, and that the shimmy of nose wheels of big aeroplanes cannot be prevented solely by solid friction damping.

Everything considered, the advantages of the nose wheel landing gear appear far to outweigh the disadvantages. The main improvement, which coincides with the general trend towards higher wing loadings, is indicated by the possibility to land aeroplanes at speeds in excess of the minimum flying speed without requiring any considerable lengthening of the landing run.

Developments in Goodrich De-Icer. (Inter. Avia., No. 761, 24/4/41, p. 14.) (92/20 U.S.A.)

The new patent, No. 2,237,175 of the B.F. Goodrich Company of New York, covers an improvement of the well-known Goodrich De-Icer system which prevents the accretion of ice at the critical points of the aeroplane mechanically, by means of pulsating rubber " overshoes." The overshoe is faired to the wing by means of a metal strip on which the ice formed could not be removed. The improvement on the method so far in use, consists of a secondary layer of soft rubber which is attached on the main de-icer, and is stretched taught over the common attachment strip. Every pulsation of the " primary " de-icer is communicated to the " secondary " overshoe and prevents the formation of ice also in the hitherto unprotected region.

American Society of Aeronautical Weight Engineers. (Inter. Avia., No. 761, 24/4/41, p. 15.) (92/21 U.S.A.)

The American Society of Aeronautical Weight Engineers has been formed for the purpose of standardising the weight indications of aircraft and simplifying the weight checking of production aeroplanes required by the delivery committees. In order to simplify the delivery formalities, it was agreed to eliminate weighing of aeroplanes in the gross weight condition, except on the first machine of a contract. Formerly the Army and Navy required that the 1st, 5th, 10th, 20th, and each succeeding 20th aeroplane of a contract be weighed in the gross weight condition. A reduction in weight empty weighings was also agreed upon; now only the 1st, 10th, 25th, and one out of each succeeding 100, as well as the last aeroplane of a contract are required to be weighed in the weight empty condition. Besides similar simplifications in the weighing of nose-wheel aircraft and flying boats, the society reached an agreement for free interchange of weight data for estimating purposes.

Douglas Method of Flush Riveting Thin Sheets for Aircraft. (Aut. Ind., Vol. 84, No. 10, 15/5/41, p. 518.) (92/22 U.S.A.)

The rivet has a cylindrical shank 3.1 mm. diameter with a conical head of 100° taper and 5.50 mm. maximum diameter. A very shallow cylindrical crown (depth 0.15 mm.) is provided on the head and this is stated to ensure a tighter fit during the subsequent closing process. The original volume of the head is 18.6 cu. mm. and the ratio of the original diameter to the original height is 4.78.

In setting the rivet, it is first inserted into the hole in the sheets with the shank extending into a tubular " bucking tool," the upper end of which is countersunk at 110.8°. One or two blows of the hammer (impact of the order of 11 ft. lb.) suffice to dimple the sheets and seat the rivet. During this operation the head diameter is increased to 6 mm. and the height reduced from 1.15 to 1 mm. The volume of the new head is now 16.9 mm. and the diameter/height ratio is increased to 6.0.

The final step consists in upsetting the shank of the rivet by a series of blows of a riveting hammer fitting snugly inside the cylindrical portion of the bucking tool. During this operation the dimpling hammer rests on top of the rivet head and acts as a countermass.

Some Experimental Results on Wing Flutter. (W. Bollay and C. D. Brown, J. Aeron. Sci., Vol. 8, No. 8, June, 1941, pp. 313-318.) (92/29 U.S.A.)

The present paper represents a progress report of some experiments being carried out in the aerodynamics laboratory of Harvard University. The first part of the experimental investigation consisted in the measurement of the vibration response curves of a wing in the wind tunnel. A wing, free to vibrate in bending and in torsion, was subjected to a forced vibration at various air

speeds up to the flutter speed. These measurements are of interest in that they show how the two natural frequencies of the wing come together as the flutter velocity is approached. The peaks of these response curves are also of interest in that they determine the maximum stresses which are experienced, for instance, by a propeller which is subjected to periodic impulses from the engine.

The second part of the investigation deals with the problem of flutter above the stall. Measurements show that at angles of attack above the positive stalling angle and below the negative stalling angle the flutter speed is decreased to less than one-third of the flutter speed of the unstalled wing. This flutter seems to be associated with an instability which arises when the slope of the lift curve becomes negative. Experiments on a metal wing supported as a cantilever indicate that the flutter at the stall may also be associated with an excitation from a system of Kármán vortices.

The Proportioning of Aircraft Frameworks. (N. J. Hoff, J. Aeron. Sci., Vol. 8, No. 8, June, 1941, pp. 319-324.) (92/30 U.S.A.)

A routine procedure, consisting of three steps, is presented for calculating the stresses in and the stability of plane frameworks. In the first step the preliminary sizes and gauges of the bars are chosen upon tentative assumptions for the end-fixity. In the second, the assumptions made are checked by rational approximate methods. In the third and last, the final check of both stresses and stability is obtained in a single step by the use of James's version of the Hardy Cross method of moment distribution. It is suggested that the procedure here described be denoted the Lundquist-Stanford method of proportioning frameworks as distinct from the Lundquist method of determining critical loads.

The Effect of Design Variables on Cargo Plane Performance. (A. Burstein, J. Aeron. Sci., Vol. 8, No. 8, June, 1941, pp. 325-330.) (92/31 U.S.A.)

The possible development of an air freight system in the United States brings up the relationship of aerodynamic design to the economical operation of cargo planes. It is shown that a careful analysis, in the light of operating costs and safety of all factors entering the design of an aeroplane is essential, if a sound design is to be evolved.

A method of evaluating the major design variables is presented. It is also shown that the operation of the plane and the degree of safety desired must be decided upon before proceeding with a design.

Because of the broad scope of the investigation, the results presented should be considered qualitatively only. However, definite trends are indicated. No fundamental aerodynamic difference exists between a well designed cargo plane and a passenger plane.

"Peravia" Engine Load Recorder. (Flugwehr and Technik, Vol. 2, No. 7, July, 1940, p. 155.) (92/32 Switzerland.)

It is customary to overhaul aero engines after a certain number of flight hours as recorded in the log book. This method of estimating the condition of the engine has the disadvantage that it is based on operation time only and no account is taken of the actual load conditions during the period. In other words, half-hour cruising is rated as equivalent to half-hour under maximum boost and this may lead to the engine being stripped when still in serviceable condition. Moreover, the checking of the log books may be difficult under war conditions and in any case requires responsible personnel. For this reason, the Peravia firm have brought out an instrument which records automatically not only the time of operation but also the induction pipe pressure. Details of the load recorder are not given, but it appears to be an engine revolution counter in which the gearing is affected by the boost pressure. Engine overhaul becomes necessary when the five-figure counter reaches a certain number.

Engine Design v. Lubrication (with Discussion). (R. J. S. Pigott, S.A.E. Journal, Vol. 48, No. 5, May, 1941, pp. 165-176.) (92/33 U.S.A.)

Attention is called to the increase in severity of conditions for lubrication in the last few years, during which the engine designer has been calling upon the oil chemist for special oils to correct difficulties in operation. The 5 per cent. increase in horse-power obtained during the last ten years is proportioned between increase of compression ratio, intake system, displacement, and speed. Increase in severity of mechanical and thermal loading is due both to increase of rotative speed and brake mean effective pressure. Cooling done by the oil has been increased, and pistons are hotter than formerly. Crankcase temperatures have risen.

Although compounding delays the start of deterioration and lowers the absolute rate, it does not prevevnt deterioration of the oil.

Too many engineering problems recently have been left to the chemist to solve. Several cases of lubrication difficulty are discussed, and a method of analysis is described which shows accurately what any oiling system will do, and can locate most of the troubles. The general fault nowadays is too low an oil flow over the bearings for cooling and unnecessarily high crankcase temperatures.

Compounded oils are bound to increase in the future, but ultimately each must cover a much wider range of usefulness than any present single oil covers. A short discussion is given on means for increasing brake horse-power without increasing the octane rating of the engine fuel.

Experimental Investigations on Freely Exposed Ducted Radiators. (W. Linke, Jahrbuch D.L.F.F., Vol. 2, pp. 381-386.) (R.T.P. Translation T.M. 970.) (92/34 Germany.)

The present report deals with the relation between the open areas, the drag, and the air flow as observed on freely exposed ducted radiators (*i.e.*, no body interference)—the air conductivity being modified from zero to one unit. The most advantageous forms of ducts are derived therefrom.

In conjunction with theoretical results, the individual components of the drag of ducted radiators are discussed and general rules established for low-loss ducts. The influence of the wall thickness of the ducts, of the length ratio of the exit, and the effects of sonic velocity on diffusers are dealt with by special measurements.

Use of Charts for Flow Discharge Calculations. (Lutz, O., L.F.F., Vol. 17, No. 8, 26/10/40, pp. 332-335.) (R.T.P. Translation T.M. 972.) (92/35 Germany.)

Various problems in connection with engine design involve flow discharge calculations which are rendered difficult both on account of the large number of external variables that enter into the computation, *i.e.*, changes in discharge area during the process, change in volume of the cylinder, pressure, etc., and changes in the thermal constants themselves of the flow medium. A fairly accurate solution that does not involve an excessive amount of labour can be obtained only through the extensive use of *I-S* tables (total heat-entropy). In the present report a simplified solution based on the tables of Lutz and Wolf is described.

Calculation of Resonance Vibrations of an Elastically-Supported Engine Mounting. (E. V. Ananiev, N. P. Serebriansky, P. G. Timofeev and A. E. Pankratov, Aeron. Eng., U.S.S.R., Vol. 15, No. 4, April, 1941, pp. 21-40.) (92/36 U.S.S.R.)

Particularly large vibrations of an engine propeller group, accompanied by correspondingly high stressing, occur under conditions of resonance, *i.e.*, when the frequency of the inciting impulses corresponds with the natural vibration

frequency of the engine mounting. By the use of flexible mounting the natural frequency of the engine mounting can be reduced below the range of possible frequencies of the inciting forces, the latter including inertia and aerodynamic forces on the propeller. The inertia forces causing vibration comprise static and dynamic unbalance, lashing of the propeller shaft in its bearings and the gyroscopic moment of a two-bladed propeller. The aerodynamic forces are due to difference in setting angle of the blades. Static and dynamic unbalance and also difference in blade setting angle cause impulses of frequency equal to the speed of revolution of the airscrew; the gyroscopic effect causes vibrations of a frequency double that of the airscrew speed. Vibrations due to the actual engine are essentially those produced by the individual cylinders, their frequency being double the crankshaft speed. Impulses due to the gas pressure may have different frequency, the lowest being half the crankshaft speed. Frequencies of the highest orders will be n, 1.5 n, 2 n, 2.5 n, etc., where n = crankshaft speed. Consequently greatest effectiveness is obtained from the elastic mounting if the following recommendations are observed:—The natural frequency of torsional vibration of the engine mounting about the axis of thrust must be lower than half the crankshaft speed, and the remaining five frequencies must be lower than the crankshaft speed, or, for an engine with reduction gearing, lower than the propeller speed. In the present paper the formulæ deduced for calculating the natural frequency are obtained by considering the engine as a solid body on elastic supports with six degrees of freedom, *i.e.*, three motions in the direction of the three main axes and three corresponding rotations about the same axes. Calculations are made for in-line and radial engines.

Effect of Temperature and Pressure of Induction Air on the Operation of an Aero Diesel. (A. E. Tolstov and D. A. Portnov, Aeron. Eng., U.S.S.R., Vol. 15, No. 4, April, 1941, pp. 41-53.) (92/37 U.S.S.R.)

Very little work has been carried out so far on the effect of supercharging on Diesel performance. The most comprehensive appears to be that of C. S. Moore and J. H. Collins (N.A.C.A. Tech. Note No. 619, 1937), but the method of investigation employed cannot be considered satisfactory since the tests were made at high fuel consumptions and at excess air coefficients (0.6 to 1.1) which are not characteristic of Diesels. In addition it is not possible from the results obtained to evaluate the effects of the individual parameters defining the condition of the induction air.

The purpose of the present work was to obtain more detailed information on the fundamental factors governing the working process in a four-stroke aero Diesel engine with supercharger and to determine experimentally the effect of a variation of the temperature and pressure at induction. The tests were made on a single cylinder air-cooled four-stroke engine, with compression ratio 14. Some preliminary conclusions are as follows:—

1. When running at constant speed and constant exhaust back pressure and fuel consumption, the brake horse-power decreases with increasing pressure of the induction air. Variation in air temperature over a fairly wide range (70-120°) had only a slight effect and for practical purposes this effect may be neglected.

2. Variation in density of the induction air has a decisive effect on the variation in mean indicated pressure, indicated fuel consumption, exhaust temperature and pressure in the combustion chamber at constant fuel consumption; this effect is independent of the cause of change in air density (pressure or temperature).

3. Increase in supercharger pressure at constant temperature improves the charging process. The volumetric efficiency increases sharply at first, and with further increase in pressure slowly approaches its maximum. Increase in induction pressure at constant fuel consumption and constant induction temperature improves the dynamics of the cycle by lowering the rate of pressure rise and reducing the thermal loading of the combustion chamber walls and piston on account of better flow through the cylinders.

4. Increase in temperature of the induction air at constant fuel consumption and constant pressure has a deleterious effect on the working process, increasing the temperature of the exhaust and reducing efficiency.

At constant excess air coefficient a temperature increase of 10° causes a decrease in mean indicated pressure of about 3 per cent.

1940 *C.F.R. Road Detonation Tests.* (J. M. Campbell and others, S.A.E. Journal, Vol. 48, No. 5, May, 1941, pp. 193-204.) (92/38 U.S.A.)

The 1940 CFR Road Tests have developed new information that can be used for the development of fuels and engines. Application of the principles worked out in these tests is expected to result in a more efficient utilisation of fuel anti-knock properties and more effective engine design and adjustment to meet the requisites of current motor fuels.

These tests indicate that the ASTM octane number alone, or even a road octane number as determined by methods heretofore widely used, does not give sufficient information for present needs relative to fuel behaviour in service. Neither do test methods previously used provide sufficient information concerning the fuel requirements and knocking characteristics of engines. The new methods of approach which have been developed, furnish needed information relative to the fuel and engine relationship that heretofore has been obscure, and indicate paths for future developments.

The entire programme has been supported generously by the co-operating organisations and their respective representatives, who actively participated in the tests. Various phases of the work have extended over most of the past year and, in the concluding and most important stage—the centralised road tests at San Bernardino, Calif.—32 organisations were represented. In these concluding tests, a study was made of the characteristics of 23 fuels, representing a wide variety of fuel types, and the complementary behaviour of 24 different automobiles. During this latter period alone, the 24 test cars were driven over 100,000 miles.

Development Work on the "Bulldog" Tractor Operating on Wood Gas. (K. Kunzel, A.T.Z., Vol. 44, No. 6, 25/3/41, pp. 149-155.) (92/39 Germany.)

The well-known "Bulldog" tractor manufactured by the firm of Lanz is fitted with a single cylinder two-stroke hot bulb engine, using crankcase compression.

Almost any type of liquid fuel can be used, provided the compression ratio is suitably adjusted. For this purpose interchangeable cylinder heads are provided.

Early experiments with wood gas fuel showed a serious drop in power (about 30 per cent. below that obtainable with fuel oil). In addition, after only forty hours operation, the engine required cleaning due to excessive crankcase deposits. This latter difficulty was completely overcome by so altering the inlet circuit that the scavenge pump in the crankcase handled air only. For this purpose, a suitable capacity was introduced into the connecting channel between cylinder and crankcase, and the automatic mixture inlet (flap valve) was placed close to the cylinder inlet.

The drop in power compared with fuel oil operation was completely avoided by injecting a small quantity of fuel oil into the cylinder (pilot ignition), and using this to fire the main charge. In the case of a 25 h.p. tractor, the quantity of oil required for this purpose is of the order of 1 Kg./hour only, the wood consumption in the generator being about 23 Kg./hour.

Abstract Note.

The use of oil pilot ignition in combination with generator gas has also given excellent results in ship propulsion, see W.R.H., Vol. 22, No. 1, Jan. 1941, pp. 41/43.

Some Peculiarities in the Working of Aircraft Fuel Systems. (G. K. Volkov, Air Fleet News, U.S.S.R., Vol. 23, No. 5, pp. 442-444.)

Operation of Aircraft Fuel Systems at High Altitudes. (M. P. Fokier, Air Fleet News, U.S.S.R., Vol. 23, No. 5, pp. 445-447.) (92/40 U.S.S.R.)

Both articles deal with the problem of vapour locks in fuel systems, giving rise to irregular running, especially at altitude.

After discussing the conditions of occurrence of vapour locks, with particular reference to the influence of accelerations in unsteady flight, the requirement is set up that the fuel system should be previously checked for correct operation under all likely conditions of flight.

The second article deals more particularly with experiments made by P. A. Pybakov on the causes of uneven running at altitude, which was found to be due principally to vapour locks in the fuel system.

The conclusion is arrived at, that vapour locks at altitude are caused principally by excessively high temperature of the fuel as taken in on the ground, in conjunction with the relative vapour tension of the fuel. Fuel grades of a vapour tension between 270-330 mm. mercury at 38°C., are considered safe from vapour lock at normal altitudes of present-day flight. It is, however, necessary to ensure that the fuel is not excessively heated while stored on the ground.

High Speed Tension Tests at Elevated Temperatures. (A. Naidai and M. J. Manjoine, J. App. Mech., Vol. 8, No. 2, June, 1941, pp. 77-91.) (92/43 U.S.A.)

The resistance to plastic deformation of several metals was investigated over a wide range of the rates of deformation and at various temperatures. The influence of the rate of strain on the forces required for plastic forming, was explored in tension tests. The fastest rate of stretching was one billion times larger than the slowest speed. At the highest velocity, corresponding to a tension test of the duration of 0.001 sec. and at temperatures close to the melting point, a remarkably large resistance to deformation was observed. In general, the stresses decrease with the temperature and increase with the rates of straining. For some ferrous metals, including a very pure iron, the resistance to deformation shows a well-defined maximum and minimum of stress as a function of the temperatures for a given strain rate. It was found that for these ferrous metals, the temperature range in which the maximum of the strength occurs, depends upon the rates of stretching. At slow rates it occurs around 200°C., while, at the very fast rates of stretching, the maximum strength is observed at 550°C. Curves showing the dependence of the resistance to deformation upon the strain rates and the temperature, are given for several metals.

In a high-speed tensile test of pure iron, an instantaneous temperature rise of about 50°C. was observed, due to the conversion of the work of deformation into heat.

It appears possible, at least in the higher range of temperature, to predict the shapes of the stress-strain curves in tension tests and the characteristic contours of bars in their necked portions. These predictions are based on a few simple assumptions as to the probable form of the relations connecting stress and the rates of strain, and are in agreement with some of the corresponding observations made at the higher testing temperatures.

Effect of Surface Finish. (J. T. Burwell and others, J. App. Mech., Vol. 8, No. 2, June, 1941, pp. 49-58.) (92/42 U.S.A.)

Surface finishes produced in various ways having roughnesses ranging from 130 to 1 micro-inch, as measured by their root-mean-square deviations from

a median plane, have little or no effect on the performance of a partial journal bearing while it is operating under hydrodynamic lubrication. There is general agreement with theory in this region, but the agreement is improved if account is taken of the breaking of the film near the outlet end of the bearing.

The lower limit of the region of hydrodynamic lubrication for a given journal-bearing combination as indicated by the minimum in the friction-co-efficient curve, is markedly dependent on the surface finish of the journal. The load capacity of the bearing increases with increasing smoothness and emphasises the great importance of reducing the surface roughness to less than 15 micro-inches at least.

A sensitive method of determining iron in oil has been developed, involving the extraction of the iron from the oil by means of hydrochloric acid. This permits the determination of 1 part of iron in 10^7 parts of oil. This method was applied to the study of the wear of a journal-bearing combination.

The effect of pressure on the running-in process was studied while maintaining a constant surface finish. The results indicate that the wear at the end of two hours increases with pressure, for the pressure range up to 1,000 lbs. per sq. in. under the ruling test conditions.

The effect of surface finish on the running-in process was measured at constant pressure. A remarkable straight-line relationship exists between the total wear at the end of two hours and the degree of surface finish, at the constant pressure employed.

It was found that the running-in period takes place in a short time, of the order of one half to one hour. The initial rate of wear is high and falls off fairly rapidly. In all cases the quantity of metal removed was quite small, being less than a millionth of an inch if it could be considered as being removed uniformly.

Analysis of Spoked Rings. (L. H. Donnell and others, J. App. Mech., Vol. 8, No. 2, June, 1941, pp. 67-73.) (92/44 U.S.A.)

The paper briefly discusses the difficulties in usual methods of studying structures with large numbers of redundancies and discusses simplifications which can be made in these methods when the structures are symmetrical. The remainder of the paper discusses the application of trigonometric series to stiffened-ring problems. General solutions are derived by using differential equations of equilibrium for the case of circular rings with continuous radial support, and by using difference equations of equilibrium for the case of polygonal rings with spokes and loads at the corners. Shear and axial strains in the ring and the difference in length of inner and outer fibres of the ring are considered. Finally, the paper shows how complete solutions can be obtained by similar methods for the case of spoked and trussed rings under loads at the joints.

Equiareal Pattern of Stress Trajectories in Plane Plastic Strain. (M. A. Sadowsky, J. App. Mech., Vol. 8, No. 2, June, 1941, pp. 74-76.) (92/45 U.S.A.)

In theoretical plasticity, all work so far done has made use of slip lines as a frame of reference. In the present paper, stress trajectories are used instead, and results of theoretical interest and practical applicability are obtained. The equiareal property of stress trajectories as derived in the present paper can be readily used to evaluate photographs of slip lines in plasticity with a higher degree of accuracy and reliability than hitherto. The analytical method can be applied to the equiareal pattern formed by stress trajectories, and formulas for stresses are obtained. An example referring to radial flow, adequately illustrates the general equiareal property.

On the Internal Resistance of Solid Bodies. (S. Higuchi, J. of Frank. Inst., Vol. 231, No. 5, May, 1941, pp. 421-445.) (92/46 U.S.A.)

Using new types of cantilever test-pieces made of seven different metals and taking the necessary precautions, the natural oscillations of these metals are carefully examined. Based on the results of these experiments, the law of the internal resistance of solids is studied.

It is concluded that the law of viscous resistance applies in the small stress region.

Surface Hardening by Induction. (Osborn, Engineer, 6/6/41, pp. 372-373.) (92/47 Great Britain.)

It is claimed that phenomenal advances have been made in the application of high frequency current to the localised surface hardening of metals. Among the advantages claimed for the process are absence of distortion and scale formation, exact repetition of conditions and an inherent increase in quality coupled with a decrease in cost. The questions of carbide diffusion and super-hardening are investigated and a brief description is given of the equipment employed in the various operations.

(Abstract supplied by Research Dept., Met. Vickers.)

An Inside Look at Welds. (Baldwin, Machinist, 7/6/41, pp. 149-152.) (92/48 Great Britain.)

Particulars are given of the technique employed by the General Electric Company of Schenectady for the examination of welds by X-rays. The use of stereoscopic location of flaws is explained and details given of the procedure and apparatus employed. A special technique has been developed for the G.E. welding school where test plates are X-rayed in groups to keep cost at a minimum.

(Abstract supplied by Research Dept., Met. Vickers.)

A New Process for Shaping Tubing to any Desired Contour. (Machinery, 12/6/41, pp. 287-290.) (92/49 Great Britain.)

Particulars are given of a new process for forming tubing to almost any regular or irregular outline, including straight tapered and rounded portions. The process is stated to be applicable to welded and seamless steel tubes up to 4 in. outside diameter and $\frac{3}{16}$ in. wall thickness in addition to non-ferrous materials. Larger tubing could be handled by a machine of greater capacity or by hot working. Tolerances of plus or minus 0.010 in. with respect both to tube diameter and wall thickness are claimed to be attainable.

(Abstract supplied by Research Dept., Met. Vickers.)

The Buckling of Thin Cylindrical Shells under Axial Compression. (T. von Kármán and H. S. Tsien, J. Aeron. Sci., Vol. 8, No. 8, June, 1941, pp. 303-312.) (92/52 U.S.A.)

In two previous papers the authors have discussed in detail the inadequacy of the classical theory of thin shells in explaining the buckling phenomenon of cylindrical and spherical shells. It was shown that not only is the calculated buckling load three to five times higher than that found by experiments, but the observed wave pattern of the buckled shell is also different from that predicted.

By a theoretical investigation on spherical shells the authors were led to the belief that in general the buckling phenomenon of curved shells can only be explained by means of a non-linear large deflection theory. This point of view was substantiated by model experiments on slender columns with non-linear elastic support. The non-linear characteristics of such structures cause the load necessary to keep the shell in equilibrium to drop very rapidly with increase in

wave amplitude once the structure started to buckle. Furthermore, as it was shown in one of the previous papers, the buckling load itself can be materially reduced by slight imperfections in the test specimen and vibrations during the testing process.

In this paper, the same ideas are applied to the case of a thin uniform cylindrical shell under axial compression. First it is shown by an approximate calculation that again the load sustained by the shell drops with increasing deflection. The results of this calculation are used for a more detailed discussion of the buckling process as observed in an actual testing machine.

Rubber Road Springs. (Macbeth, Auto. Engr., June, 1941, pp. 195-199.) (92/50 Great Britain.)

The development of rubber springing is first outlined and points that have influenced rubber technologists are set out in detail. The question of the form of stress most likely to furnish best results in a vehicle suspension is discussed together with various methods of holding or attaching the rubber to its component parts or housing. A scheme is outlined based on the use of a conical torsion disc and the tests and testing rig are described.

(Abstract supplied by Research Dept., Met. Vickers.)

Re-Crystallisation Theory on an Atomistic Basis. (V. Dehlinger, Z.f. Metallkunde, Vol. 33, No. 1, Jan., 1941, pp. 16-20.) (92/53 Germany.)

Any cold working of a crystalline material leads to profound changes in structure. Under certain conditions these changes may subsequently disappear as a result of a kinetic process termed "re-crystallisation." An atomiatic theory of this process must attempt to describe the motion of the atoms during this period of recovery and this entails some knowledge of the atomic structure of the deformed material. Studies with single crystals have shown that a cold worked multi-crystalline material experiences two kinds of lattice distortion characterised by very different degrees of stability.

1. Displacement of the lattice, which can be relieved by a jump of individual atoms, producing the well known phenomenon of recuperation.
2. A distortion of complete lattice sections which can only be eliminated by reactions of a higher order, *i.e.*, the formation of re-crystallisation of nuclei.

These nuclei are practically free from distortion energy and their subsequent growth is very similar to that occurring in normal solidification of the molten material.

Scratch Hardness in C.G.S. Units. (W. Ehrenberg, Z.f. Metallkunde, Vol. 33, No. 1, Jan., 1941, pp. 22-23.)

Quantitative Relationship between Scratch and Pressure Hardness. (do., p. 23.) (92/54 Germany.)

The surface of a material can be damaged in two distinct ways:—

1. The constituent particles are displaced, an indentation being formed.
2. Particles are torn away, *i.e.*, the surface is scratched.

The measurement of indentation resistance has become standardised and is expressed as load/area of impression (Brinell hardness, etc.). It is easily determined and in many cases allows useful conclusion to be drawn concerning other mechanical characteristics of the material (ultimate tensile and fatigue limits) requiring much more elaborate apparatus for their direct evaluation.

Such qualities as resistance to wear or machinability of the surface, however, cannot be expressed in terms of pressure or indentation hardness, since now the material is no longer deformed but actually torn away. It is clear that in this case a determination of the resistance to scratching (so-called scratch hardness) would be very useful. Whilst several simple methods of recording scratch hard-

ness are available, they have suffered from the fact that the scales adopted so far have been arbitrary and not expressible in C.g.S. units.

The author proposes a definition of scratch hardness in terms of load per unit area of slip surface.

If γ = vertex angle of cone producing scratch.
b = width of scratch (mm.).
G = load in Kg.

$$\text{Scratch hardness} = \frac{8G \sin(\gamma/2)}{b^2\pi} \text{ Kg./mm.}^2.$$

The pressure hardness obtained with the same cone is defined as :—

$$= \frac{4G \sin(\gamma/2)}{d^2\pi} \text{ Kg./mm.}^2.$$

where d = diameter of circular indentation obtained after a load period of 30 seconds.

The author has carried out a most interesting set of experiments on the variation of scratch and pressure hardness with G for a number of materials. The load range varied from 5 gm. to 10 Kg. A polycrystalline material is practically homogeneous towards deep scratches, and under these conditions the two hardness numbers approximate. If, however, the depth of scratch approaches the dimensions of the constituent grains, marked differences appear, the scratch hardness becoming a minimum whilst the pressure hardness is a maximum. If the scratch is smaller than the average grain size, the pressure hardness falls rapidly whilst the scratch hardness increases.

By means of these relatively simple experiments considerable light is thus thrown on the structure of the material.

Surface Cracks of Cladded Al-Cu-Mg Alloys Undergoing Reversed Bending. (H. Burnheim and R. Mechel, Z.f. Metallkunde, Vol. 33, No. 1, Jan., 1941, pp. 25-27.) (92/55 Germany.)

Samples of high grade cladded Al-Cu-Mg sheets undergoing reversed bending showed a considerable roughening of the surface due to formation of surface cracks in the protecting layer long before the ultimate failure of the core. These cracks are due to differences in the yield point and fatigue limits of protecting surface sheet and core. If the reversed bending stress is of the order of the yield point of the core (*i.e.*, failure after a few thousand cycles) surface roughening becomes apparent almost immediately. For lower bending stresses corresponding to an endurance of 10^7 cycles, the surface cracks take longer to develop and are fewer in number. On the other hand the cracks are now much deeper, some of them projecting right into the core. It is clear that such cracks may effect the fatigue strength of the core (notch sensitivity). In any case they will reduce the corrosion resistance of the combination.

The Influence of Impurities on the Corrosion Resistance of Mg and its Alloys with Mn and Al. (A. Beerwald, Z.f. Metallkunde, Vol. 33, No. 1, Jan., 1941, pp. 28-31.) (92/56 Germany.)

After obtaining Mg of a very high degree of purity by means of distillation in vacuum, the author investigated the effect of small additions of Fe and Cl on the corrosion resistances of Mg and Mg-Mn-Al alloys (attack by 0.3 per cent. salt solution). The so-called eudiometer method was employed in which the quantity of H_2 liberated is measured over a time basis.

The results show that the presence of small quantities of iron is most active in promoting the corrosion of Mg and Mg-Al alloys. The presence of as little as 0.005 per cent. Fe trebles the corrosion rate compared with that of pure Mg, the effect reaching a maximum at 0.02 per cent. Fe. Similar results apply to Mg-Al alloys.

On the other hand, the presence of iron does not affect the high corrosion resistance of Mg-Mn alloys.

Chlorine, unless present in the form of slag inclusions, appears to have no effect on the corrosion resistance.

The Mechanical Properties of Solids. (E. N. da Costa Andrade, J. Inst. Civil Engineers, Vol. 16, No. 7, June, 1941, pp. 287-308.) (92/57 Great Britain.)

The mechanical properties of solids depend largely on the previous history of the sample. This even applies to single crystals. Such crystals are quite soft when first made, and a crystal rod of copper $\frac{1}{2}$ in. diameter can be easily bent by hand. To straighten the rod after bending is, however, much more difficult, due to strain hardening of the material. This hardening is due to the irreversible nature of the slip phenomena which are fully discussed by the author. It appears that the tensile strength of most engineering materials is considerably below theoretical values. The author attributes this to surface imperfections leading to considerable stress concentrations. Such imperfections are more likely to persist in metallic crystalline conglomerates, and it may be possible to develop alternative non-crystalline materials of vastly improved strength characteristics.

The Steady Flow of Heat from Certain Objects Buried Under Flat Air-Cooled Surfaces. (F. H. Schofield, Phil. Mag., Vol. 31, No. 209, June, 1941, pp. 471-497.) (92/58 Great Britain.)

A general method of estimating the steady flow of heat from, and the temperature distribution around, objects buried under flat air-cooled surfaces is developed for a considerable class of two-dimensional problems. By this method, an approximate solution of the problem is at once derived from the simpler solution of the corresponding problem in which the sink of heat, instead of being, as required, a surface subject to Newton's law of cooling, is an isothermal surface.

A critical examination of the method is made, with satisfactory results, in three practical cases, viz.:—

1. A pipe or cable buried in the ground.
2. The same in a wall.
3. A girder or ship's rib projecting into a wall.

The Propagation of Sound in the Free Atmosphere and its Dependence on Meteorological Conditions. (H. Sieg. El. Nachrichten, Technik, Vol. 17, No. 9, Sept., 1940, pp. 193-208.) (92/59 Germany.)

Wind is by far the most important meteorological factor influencing the propagation of sound. Pure temperature effects only become marked in practically calm weather. In the latter case, the minimum reduction in sound intensity with distance is of the order of 1 db./100 m. for the frequency range 250-4,000 vibration/sec. A clouded sky, fog and drizzle favour the carrying power of the sound. Atmospheric turbulence is detrimental.

Due to molecular absorption, high frequency notes are absorbed more readily than sounds of lower pitch, and this becomes more marked the higher the frequency.

The propagation is also influenced by the height of the source above ground. If the transmitter is in close proximity to the ground, the propagation of high frequency notes is favoured.

Requirements of a Smoke Meter. (K. M. Brown, S.A.E. Journal, Vol. 48, No. 5, May, 1941, pp. 188-192.) (92/61 U.S.A.)

The necessity of being able to evaluate the degree of smoke in the Diesel engine exhaust is becoming universally recognised. Various methods of measuring smoke are discussed briefly.

Of these methods, the light-absorption, photo-electric cell, sampling-type smoke meter appears to the the most satisfactory.

Design requirements are listed, and a smoke meter is described which appears to meet them with reasonable satisfaction. The principal departures in the design of this smoke meter from that of others of the same type are in the greater length of the measuring tube, the use of a flashlamp type bulb with reflector for a light source, and the use of a vacuum pump to draw the sample through the smoke meter.

The term " smoke density per unit of smoke column " is proposed as the basis of a standard scale.

Temperature Distribution in Light Alloy Billets during Heating and Cooling. (W. Roth, Z.f. Metallkunde, Vol. 33, No. 1, Jan., 1941, pp. 13-15.) (92/60 Germany.)

The author investigates mathematically the following problems:—

(1) An infinitely long bar at room temperature is suddenly exposed to a gas temperature of 500°C. How does temperature at centre of bar vary with time (air quiescent)?

(2) The infinitely long bar at 500°C. throughout is suddenly exposed to cold air at room temperature—variation of temperature at centre with time (air quiescent).

(3) Temperature difference between centre and surface of bar both during heating and cooling as above, as a function of temperature at centre.

(4) Surface temperature of bar originally at room temperature throughout is suddenly raised to 500°C. and kept at that value. Variation of temperature at centre with time.

(5) Surface temperature of bar originally at 500°C. throughout is suddenly reduced to 100°C. and kept at that value. Variation of temperature at centre with time.

The calculations show that under conditions (1) and (2) (quiescent air) the maximum temperature difference between centre and surface of bar is less than 10°C. for a bar diameter of 400 mm. and about 2.5°C. for a bar diameter of 100 mm. Sudden immersion in a salt bath (at 500°C.) or sudden quenching in water (100°C.) naturally produces large temperature differences between centre and core in the first instance. These differences disappear, however, in a few minutes, and even in the most unfavourable case (diameter 400 mm.) core and surface are at practically the same temperature after ten minutes.

A New High Speed Indicator System (Digest). (E. E. Simmons, S.A.E. Journal, Vol. 48, No. 5, pp. 23-24.) (92/62 U.S.A.)

Extending the use of the bonded resistance gauge to fluid pressure measurement provides several important advantages over present apparatus, especially for high speed and high pressure applications. In one arrangement, a piston or diaphragm actuates a dynamometer bar upon which is attached a strain-sensitive winding. An element of this type may be assembled in a threaded plug for easy attachment to a combustion or pressure chamber. Pressure plugs of good dynamic accuracy capable of static calibration are feasible for pressures as high as those existing in gun chambers.

A second arrangement utilises the radial expansion of a tubular structure under pressure to actuate a bonded strain winding. A closed-end tube fitted into a threaded plug provides a useful indicator pressure element. Through type tubular gauges furnish a simple method of observing pressures existing during fluid flow, as in Diesel injection or rifle operation. Such gauges can be constructed to cover the full range of pressure measurement.

Experience with Flow Direction Instruments. (B. Eckert, Jahrbuch D.L.F.F., 1938, Vol. 2, pp. 381-386.) (R.T.P. Translation T.M. 969.) (92/63 Germany.)

Instrument for measuring flow direction may be of the direct or indirect type. The former method is generally only applicable in specially very extensive flows, the flow direction being given by the angle of yaw of the recorder with respect to some fixed plane of reference. Instruments of the indirect type are provided with a number of orifices placed at certain angles and the direction of flow is obtained from the pressure record, making use of a calibration curve. Such instruments have the advantage of only requiring very little space.

The principal instruments described in the article are listed below:—

(*a*) *Two-dimensional flow*—
Prandtl pitot.
Sers plate.
Double pitot.
Cylindrical tube with openings.

(*b*) *Three-dimensional flow*—
Dynamic pressure claw with three pitots.
Dynamic pressure claw with five pitots.
Spherical pitot.
Spherical pitot with transverse flow effects.

The author concludes that the method of recording flow direction on the basis of the hydrodynamic zero point measurement has now reached a certain limit as to possible accuracy. The next problem will be to achieve a point by point flow direction record of greater accuracy with simplified test procedure.

Elastic Mounting of Quartz Crystal to Eliminate Inertia Effects in Piezo Electric Pressure Indicators. (J Kluge and others, 2 fur Instrumenten Kunde, Vol. 61, No. 2, Feb., 1941, pp. 65-66.) (92/64 Germany.)

In the normal piezo electric indicator, the quartz crystal abuts against a rigid wall and the electric charge generated is thus affected by the inertia of the crystal. This leads to errors in the pressure record and, moreover, may cause the crystal to crack. To obviate these difficulties, the authors mount the quartz between two diaphragms of equal stiffness so that the crystal is subjected to a preliminary compression. Inertia forces due to the crystal itself will cause a reduction of contact pressure on one side and a corresponding increase on the other, *i.e.*, the resultant electric charge is zero. Whilst this mounting thus automatically compensates for inertia effects, the sensitivity of the instrument is reduced, since a portion of the pressure is now absorbed by the diaphragms.

The same principle can also be applied to piezo electric indicators of the piston type.

If
M_d = mass of piston assembly.
M_Q = mass of quartz crystal.
C_1 = stiffness of front diaphragm.
C_2 = stiffness of rear diaphragm.

Inertia compensation is effected if

$$\frac{C_1}{C_2} = \frac{(2\,M_d + M_Q)}{M_Q}$$

It is stated that an instrument designed on these lines proved highly successful.

Mercury Vapour Lamps for Electric Flashlight Stroboscopes. (P. Drewell, Z.f. Instrumentenkunde, Vol. 61, No. 3, March, 1941, pp. 99-100.) (92/65 Germany.)

For stroboscopic purposes, the ordinary Neon lamp suffers from the drawback of very low light intensity. The author describes an electric circuit for the

starting and quenching of a high pressure mercury vapour lamp (six atmospheres). The duration of the flash is of the order of 2×10^{-5} sec., its intensity 800,000 Heffner candles. It is stated that the discharge current of the lamp is of the order of 3,000 amp.

A Flashlight Time Interval Recorder Suitable for Short and Medium Intervals. (K. Botz, Z.f. Instrumentenkunde, Vol. 61, No. 4, April, 1941, pp. 135-136.) (92/66 Germany.)

The device is intended mainly for ballistic research, the projectile passing through two wire coils placed at a suitable distance apart. The passage through the first coil generates a current impulse which discharges a high tension condenser, the resultant spark illuminating a rotating scale. A second spark is generated by passage through the second coil. Both scale images are photographed on the same film, the optical arrangement being such that the two portions of the scale appear immediately above one another. The drum carrying the scale rotates at 100 rev./sec., this speed being controlled stroboscopically to an accuracy of 0.01 per cent. The time interval between the two sparks is measured by the difference between any two vertical scale readings and is thus unaffected by distortion of the film during development. As there are 100 graduations, a displacement of one scale division corresponds to 10^{-4} sec. By reading 1/10 divisions, time intervals of the order of 10^{-5} seconds are recorded. By means of a special switch, both sparks can be released in series and the electrical time lag (of the order of 0.5×10^{-6} sec.) determined directly.

In order to measure longer time intervals (of the order of 1 sec.) a second scale rotating at 1 rev./sec. is incorporated, the photographs of the two scales being superposed as before.

Note on the Paper: "A New Determination of the Viscosity of Air by the Rotating Cylinder Method." (G. Kellstrom, Phil. Mag., Vol. 31, No. 209, June, 1941, 466-470.) (92/67 U.S.A.)

Attention has been drawn to two corrections to the simple theory of the rotating cylinder method, which have not been considered in earlier determinations of η by this method—the end-correction to the length of the inner cylinder and the correction for the influence of the air on the effective moment of inertia of the inner cylinder. In the present paper the influence of these corrections on the writer's earlier η value is calculated.

As the two corrections act in different directions, the resulting correction is very small. Owing to the uncertainty in the calculation, however, the limit of error ought to be raised a little, and the final result may therefore be written :—

$$\eta_{20^\circ} = (18{,}204 \pm 30)\ 0.10^{-8},$$
$$\eta_{23^\circ} = (18{,}352 \pm 30)\ 0.10^{-8}.$$

Administrative Report of the N.A.C.A. for the Fiscal Year ending June 30th, 1940. (92/68 U.S.A.)

The total amount allocated for general purpose amounted to 2.02 million dollars, of which 1.39 million dollars were spent on personal services. The expenditure on printing comes out of a separate fund (23,000 dollars).

In addition to the above, 2.22 million dollars were spent during the year under review on improvements and new equipment at Langley Field Laboratory, whilst a further 2.6 million dollars went towards the equipment of the new Ames Laboratory at Moffat Field, California, the flight research department of which is now in operation.

The work of the following committees is briefly reviewed :—

Main Committees.

Aerodynamics.

Power plant for aircraft.

Aircraft materials.
Aircraft structure.

Sub-Committees.

Meteorological problems.
Seaplanes.
Vibration and flutter.
Fuel and lubricants.
Supercharger compressors.
Exhaust gas turbines and inter-coolers.
Miscellaneous material and accessories.

In order to ensure close contact with other research activities in the U.S.A. a special co-ordination office has been set up and arrangements have been made for the research personnel to be in close touch with manufacturers. During the year under review, three technical reports and thirty-three technical notes of outstanding interest were released for publication. In addition forty-three translations from the foreign technical and scientific press were issued.

At the request of the United States Army and Navy, both Reports and Notices were placed on the restricted status on June 1st, 1940, and subsequent numbers are not available for general distribution.

The following paragraph is taken from the concluding remarks of the Chairman:—

"It is the responsibility of the N.A.C.A. to anticipate the research needs of aviation and the progress that can be made and to furnish the Army, the Navy, and the industry in the United States with a constant flow of the new knowledge that is essential to American leadership in aircraft performance."

Characteristics of Fire Jets. (J. S. Blair, J. Inst. Civil Engineers, Vol. 16, No. 7, June, 1941, pp. 354-380.) (92/69 Great Britain.)

In view of the scanty information available, the author carried out a series of tests dealing with the heights and throws of water jets at all angles and in particular the throws obtainable with limited rise of jet trajectory above the nozzle was investigated. This is of importance when fighting fires in constricted passages.

The programme of tests covered the following points:—

(1) Nozzle efficiency and relationship between discharge and pressure.
(2) Loss of pressure in fire hose.
(3) Relationship between height of jet, angle of projection and pressure.
(4) Relationship between throw of jet, angle and pressure.

The results are given in a series of tables covering the following standard sizes of nozzle $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$ and 1 in.

LIST OF SELECTED TRANSLATIONS.

No. 35.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft Production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

Aero- and Hydrodynamics.

Translation number and author.		Title and reference.
1198	Poggi, L.	*The Velocity Field in a Two-Dimensional Flow of Compressible Fluid.* (L'Aerotecnica, Vol. 12, No. 12, Dec., 1932, pp. 1,579-1,593.)
1199	Eck, B.	*Theory and Design of Propeller Fans (Axial Blowers).* (Ventilatoren, 1937, Section B, pp. 137-169, Section C, 178-185.)

Aircraft and Accessories.

1203	Hartwig, G. ...	*The Break-away of the Wing Flow as affected by Flaps and Wing Fittings (Engine Nacelles and Fuselage).* (L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 40-46.)
1207	Krumbholz, H. ...	*Some Notes on the Frequency of Gust Loads on Wings.* (L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 82-85.)
1212	Toulyakov, V. P. ...	*Experimental Research on Undercarriage Loads and the Efficiency of Shock Absorbers.* (Aeron. Eng., U.S.S.R., Vol. 15, No. 1, Jan. 1941, pp. 44-52.)

Engines and Accessories.

1204	Brode, K.	*Three New Engines of the B.M.W. 132 Series.* (Luftwissen, Vol. 8, No. 2, Feb., 1941, pp. 57-59.)
1208	List, H.	*Flow Phenomena in the Induction Pipes of Internal Combustion Engines.* (Z.V.D.I., Vol. 85, No. 13, 29/3/41, pp. 301-305.)
1209	Hoff, W.	*Non-Dimensional Expressions for the Performance of the Airscrew Engine Combination.* (L.F.F., Vol. 17, No. 10, 26/10/41, pp. 299-305.)
1215	Sabel, R.	*General Problems Connected with the Cooling of Engines during High Altitude Flight.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 2, pp. 257-270.)

Materials and Elasticity.

1206	Karas, F.	*Fatigue Strength of Bearing Surfaces Against Pitting.* (Z.V.D.I., Vol. 85, No. 14, 15/4/41, pp. 341-343.)
1210	Rossow, E.	*Materials for Aero Engine Gears.* (Luftwissen, Vol. 8, No. 3, March, 1941, pp. 86-90.)
1214	Hemel, M.	*Fatigue Characteristics of Ordinary Malleable Cast Iron.* (Z.V.D.I., Vol. 85, No. 12, 22/5/41, pp. 290-292.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING JUNE, 1941, TOGETHER WITH LIST OF NEW TRANSLATIONS RENDERED AVAILABLE.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of the Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example that published by the Aeronautical Research Committee) is already known to these Staffs.

Theory and Practice of Warfare.

77/1 Great Britain *North American NA-40 Bomber (Photograph).* (Aeroplane, Vol. 60, No. 1,563, May 9, 1941, p. 512.)

77/2 Great Britain *Douglas B-19 Nearing Completion (Photograph).* (Aeroplane, Vol. 60, No. 1,563, 9/5/41, p. 512.)

77/3 Great Britain *New Italian Bombers (Fiat R.S. 14 Seaplane and Cant Z1008 Landplane, Breda 210 (=Ju. 87B) Dive Bomber).* (Aeroplane, Vol. 60, No. 1,563, 9/5/41, p. 513.)

77/4 Great Britain *Me. 109 Bomb Attachment (Photograph).* (Aeroplane, Vol. 60, No. 1,563, 9/5/41, p. 520.)

77/5 Great Britain *Focke Wulf F.W. 189 Army Co-operation.* (Aeroplane, Vol. 60, No. 1,563, 9/5/41, p. 524.)

77/6 Great Britain *Curtiss (XSB2C-1) Dive Bomber.* (Flight, Vol. 39, No. 1,689, 8/5/41, pp. 333-334.)

77/7 Great Britain *Hawker Typhoon.* (Aeroplane, Vol. 60, No. 1,562, 2/5/41, p. 485.)

77/8 Great Britain *Fiat Cr 32 Bis Single-Seat Fighter.* (Aeroplane, Vol. 60, No. 1,562, 2/5/41, p. 494.)

77/9 Great Britain *The Birth of the Typhoon.* (C. M. Poulsen, Flight, Vol. 39, No. 1,689, 8/5/41, p. 328 F and H.)

77/10 Germany ... *New Solution of the First Main Problem of External Ballistics.* (K. Eggens Wiss, Abh. Reichsamt f. Wetterdienst, Vol. 5, No. 11, 1939, pp. 11-16.) (Zent B, Vol. 10, No. 4, 11/11/40.)

77/11 Germany ... *Anti-Aircraft Ballistics.* (I. Sintes, Compt. Rend. Acad. Sci. Roum., Vol. 3, 1939, pp. 263-268, 9-558, 683-690.) (Zent B, Vol. 10, No. 4, 11/11/40.)

77/12 Germany ... *Mathematical Calculation of the Impact Force of Bombs.* (F. Frey, Schweiz Techn. Zeit, No. 24, 1940, pp. 293-294.) (Zent B, Vol. 10, No. 4, 11/11/40.)

77/13 Great Britain *Features of the Liberator (Production Process of Consolidated B-24 Four-Engined Bomber).* (Airc. Prod., Vol. 3, No. 31, May, 1941, pp. 156-160.)

77/14 U.S.A. ... *Curtiss XSB2C-1 Dive Bomber.* (American Aviation, Vol. 4, No. 21, 1/5/41, p. 6.)

77/15 U.S.A. ... *Production Figures for American Aircraft Engines.* (American Aviation, Vol. 4, No. 21, 1/5/41, p. 38.)

77/16 U.S.A. ... *Northrop Five-ton Patrol Bomber.* (American Aviation, Vol. 4, No. 21, 1/5/41, p. 43.)

77/17 U.S.S.R. ... *The Tactics of Aviation in the Present War.* (V. V. Marrin, Air Fleet News, Vol. 23, No. 3, March, 1941, pp. 201-207.)

77/18 U.S.S.R. ... *Air Defence Against Troop Landings (by the Navy).* (D. U. Marchurow, Air Fleet News, Vol. 23, No. 3, March, 1941, pp. 213-215.)

77/19 U.S.S.R. ... *Calculation of the Ballistic Elements for Firing in the Air (contd. from No. 2).* (V. S. Pugachev and B. K. Blinov, Air Fleet News, Vol. 23, No. 3, March, 1941, pp. 217-228.)

77/20 U.S.S.R. ... *The Use of Armour in Aircraft.* (N. I. Shaurov, Air Fleet News, Vol. 23, No. 3, March, 1941, pp. 243-247.)

77/21 Great Britain *Boeing B. 17C Flying Fortress (Photograph).* (Flight, Vol. 39, No. 1,690, 15/5/41, p. 340.)

77/22 Great Britain *Lockheed "Lightning" Twin-Engined Single-Seater Fighter.* (Flight, Vol. 38, No. 1,690, 15/5/41, p. 341.)

77/23 Great Britain *Focke-Wulf 189 Reconnaissance Fighter.* (Flight, Vol. 39, No. 1,690, 15/5/41, p. 341.)

77/24 Great Britain *The American Fighter (Comparison with British Types).* (J. I. Waddington, Flight, Vol. 39, No. 1,690, 15/5/41, p. 344.)

77/25 Great Britain *Republic "Thunderbolt" Fighter.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 539.)

77/26 Great Britain *Douglas "Boston" and "Havoc" Twin-Engined Bomber.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 538.)

77/27 Great Britain *Mass Production of Ju. 88.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 545.)

77/28 Great Britain *Boeing Flying Fortress.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 546.)

77/29 Great Britain *Curtiss 81A Tomahawk.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 548.)

77/30 Great Britain *American Aviation To-day as a Decisive Factor in World Affairs.* (J. Franklin Inst., Vol. 231, No. 3, March, 1941, pp. 203-221.)

77/31 Great Britain *Standardisation in War Time.* (Engineering, Vol. 151, No. 3,928, 25/5/41, p. 331-332.)

77/32 Germany ... *Dive Bombing.* (H. Wenke, Luftwissen, Vol. 8, No. 4, April, 1941, p. 115-117.)

77/33 Germany ... *Rescue Pontoon for Aircraft Crews Forced Down on the Water.* (Luftwissen, Vol. 8, No. 4, April, 1941, p. 128.)

77/34 U.S.S.R. ... *Barrage Balloons.* (M. Tsaig, Aeroplane, U.S.S.R., No. 2-24, 1940, pp. 30-32.)

77/35 U.S.S.R. ... *Dive Bombing in Sea Warfare.* (D. U. Marchukov, Air Fleet News, U.S.S.R., Vol. 23, No. 1, January, 1941, pp. 17-22.)

77/36 U.S.S.R. ... *Winter Camouflage of Aircraft.* (S. Y. Mirontsev, Air Fleet News, U.S.S.R., Vol. 23, No. 1, Jan., 1941, pp. 34-40.)

77/37 U.S.S.R. ... *Fire from an Aircraft on Stationary and Mobile Ground Targets.* (S. D. Sapunov, Air Fleet News, U.S.S.R., Vol. 23, No. 1, Jan., 1941, pp. 49-56.)

77/38 Great Britain *Facts About the Rifle.* (D. Weir, Engineer, Vol. 171, No. 4,453, 16/5/41, pp. 314-316.)

77/39 Great Britain *The Physics of Air Raids.* (J. D. Bernal, Nature, Vol. 147, No. 3,733, 17/5/41, pp. 594-596.)

77/40 U.S.A. ... *Training for National Defence.* (A. A. Potter, Mech. Eng., Vol. 63, No. 3, March, 1941, pp. 183-194.)

77/41 Canada ... *P.39 Airacobra.* (R. A. Keith, Canadian Aviation, Vol. 14, No. 4, April, 1941, pp. 27-30.)

77/42 Canada ... *Fairchild M. 62 Primary Trainer.* (Canadian Aviation, Vol. 14, No. 4, April, 1941, pp. 35-36.)

77/43 Great Britain *Blackburn Botha Reconnaissance Bomber.* (Aircraft Engineering, Vol. 13, No. 147, May, 1941, pp. 131-136.)

77/44 Switzerland... *North American NA-73 "Mustang" Single-Seat Fighter.* (Inter. Avia., No. 759, 9/4/41, p. 7.)

77/45 Switzerland... *Fleetwing XBT-12 Basic Trainer.* (Inter. Avia., No. 759, 9/4/41, p. 7.)

77/46 Switzerland... *New German Military Equipment (F.W. 187 and H.E. 177).* (Inter. Avia., No. 759, 9/4/41, p. 10.)

77/47 Switzerland... *Savoia Marchetti S.M. 185 Twin-Engined Dive Bomber.* (Inter. Avia., No. 759, 9/4/41, pp. 10-11.)

77/48 U.S.S.R. ... *Independent Operations by Air Forces (from Experience in the War in Europe).* (P. P. Yusupov, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 9-16.)

77/49 U.S.S.R. ... *Combined Action by Fighters and Bombers.* (M. M. Kieselev, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 22-26.)

77/50 U.S.S.R. ... *Sights for Aircraft Machine Guns.* (M. Alekseev, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 56-58.)

77/51 U.S.S.R. ... *Preparation of Aircraft Weapons for Firing at High Altitudes.* (H. Kumpiak, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 67-68.)

77/52 U.S.S.R. ... *The Hungarian Air Force.* (Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 75-76.)

77/53 U.S.A. ... *American Motor Torpedo Boats.* (Sci. Am., Vol. 164, No. 5, May, 1941, p. 281.)

77/54 Great Britain *Troops by Air (Towing Method for Trailers).* (B. Foster, Flight, Vol. 39, No. 1,692, 29/5/41, pp. 371-373.)

77/55 Great Britain *The Place of the Dive Bomber (German and American Equipment).* (Flight, Vol. 39, No. 1,692, 29/5/41, pp. A-D.)

77/56 Great Britain *Facts about the Rifle No. II.* (D. Weir, Engineer, Vol. 171, No. 4,454, pp. 330-333.)

77/57 Great Britain *Explosives.* (G. I. Finch, Engineer, Vol. 171, No. 4,454, pp. 340-341.)

77/58 U.S.A. ... *Mass Production of Skilled Workers in the U.S.A.* (E. L. Warner, Autom. Ind., Vol. 84, No. 7, April, 1941, pp. 363-367, 400-402.)

77/59 U.S.A. ... *F.W. 187 "Destroyer" (Photograph).* (Autom. Ind., Vol. 84, No. 8, 15/4/41, p. 417.)

77/60 U.S.A. ... *Fire Fighting with CO_2 (Low and High Pressure System).* (Autom. Ind., Vol. 84, No. 8, April 15, 1941, pp. 424-425.)

77/61 U.S.A. ... *Consolidated P.B. 272 Bomber (Photograph).* (Autom. Ind., Vol. 84, No. 8, 15/4/41, pp. 447.)

77/62 Germany ... *Recent Development of German Military Arc Lamp Searchlights.* (W. Rohloff, Electrotech. Zeit., Vol. 61, 2/5/40, pp. 389-394.) (Sci. Abstr. B, Vol. 44, No. 520, April, 1941, p. 63.)

77/63 Great Britain *Messerschmitt Me. 109 F Fighter.* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 566.)

77/64 Great Britain *Douglas "Digby" Two-Motor Bombers (Military Version D.C.3, also known as B18A and D.B. 280. D.B. 320 is a later Version).* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 572.)

77/65 Great Britain *American Views on Development during Production.* (H. C. Hill, Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 576.)

77/66 Great Britain *Curtiss S.B. 2C-1 Dive Bomber (Photograph).* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 579.)

77/67 Great Britain *P.39C. Bell Airacobra (Caribou) (Photograph).* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 579.)

77/68 Great Britain *Lockheed P.38 Fighter (Lightning) (Photograph).* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 579.)

77/69 Great Britain *Martin B.26 "Marauder" Twin-Engined Day Bomber (Photograph).* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 578.)

77/70 France ... *Bombing by Day (II. The Fighter Bomber).* (C. Rougeron, Inter. Avia., No. 748-749, 6/2/41, pp. 1-4.)

77/71 Great Britain *Blackburn Botha Twin-Engined Reconnaissance and Torpedo Plane.* (Inter. Avia., No. 748-749, 5/2/41, p. 7.)

77/72 Japan ... *Nozawa X-1 Light Trainer.* (Inter. Avia., No. 748-749, 6/2/41, p. 10.)

77/73 Japan ... *"Plastic" Trainers Built in Canada.* (Inter. Avia., No. 748-749, 6/2/41, p. 10.)

77/74 U.S.A. ... *Martin B.26 Twin-Engined Medium Bomber.* (Inter. Avia., No. 748-749, 6/2/41, p. 11.)

77/75 U.S.A. ... *Martin 187 Twin-Engined Attack Bomber "Baltimore."* (Inter. Avia., No. 748-749, 6/2/41, p. 11.)

77/76 U.S.A. ... *Martin P.B.M.-1 Long Range Patrol Bomber.* (Inter. Avia., No. 748-749, 6/2/41, p. 11.)

77/77 U.S.A. ... *Douglas 8A-5 Single-Engined Attack Bomber.* (Inter. Avia., No. 748-749, 6/2/41, p. 12.)

77/78 U.S.A. ... *Cessna AT-8 Transition Trainer.* (Inter. Avia., No. 748-749, 6/2/41, p. 12.)

77/79 U.S.A. ... *Ryan ST-3 (PT-20A) Trainer.* (Inter. Avia., No. 748-749, 6/2/41, pp. 12-13.)

77/80 U.S.A. ... *U.S.A. Wireless Controlled Target Aircraft.* (Inter. Avia., No. 748-749, 6/2/41, pp. 17-18.)

77/81 Italy ... *Piaggio P.23R. Three-Engined Bombers.* (Inter. Avia., No. 756-757, 27/3/41, p. 7.)

77/82 Italy ... *Fiat B.G.A. Heavy Bomber (Two Engines).* (Inter. Avia., No. 756-757, 27/3/41, pp. 7-8.)

77/83 Italy ... *Caproni 335 "Maestrale" Two-Seat Fighter (Identified with SABCA S.47).* (Inter. Avia., No. 756-757, 27/3/41, p. 8.)

77/84 Italy ... *Caproni 602 and 603 Aerobatic Trainer.* (Inter. Avia., No. 756-757, 27/3/41, pp. 8-9.)

77/85 U.S.A. ... *Vultee 72 Fitted with Liquid-Cooled Engines (Vanguard, Vengeance).* (Inter. Avia., No. 756-757, 27/3/41, p. 11.)

77/86 U.S.A. ... *NA-73 "Mustang" Single-Seat Fighter.* (Inter. Avia., No. 756-757, 27/3/41, pp. 12-13.)

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77/391 U.S.A. ... *Visibility and Seeing.* (M. Luckiesh and F. K. Moss, Franklin Inst., Vol. 231, No. 4, pp. 323-343, April, 1941.) (Abstract available.)

77/392 U.S.S.R. ... *Precautions to be Observed in Winter in Using a Twin-Engined Aircraft wit M-100 Engines.* (E. P. Bezgramotny, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 59-64.)

77/393 U.S.A. ... *Supercharging the Pilot (Removal of Dissolved N_2 by O_2 Inhalation).* (A. Klemin, Sci. Am., Vol. 164, No. 5, May, 1941, pp. 302-303.)

77/394 Great Britain *Visibility by White and Coloured Lights.* (J. S. Dow, Engineering, Vol. 151, No. 3,930, 9/5/41, pp. 373-374.)

77/395 Great Britain *Photo-Electric Humidity Measurement.* (C. Strobel, E.T.Z., 6/6/40, pp. 515-518.) (Met. Vick. Tech. News Bull., No. 762, 16/5/41, p. 9.)

77/396 Great Britain *High Altitude Flying.* (Flight, Vol. 39, No. 1,693, 2915/41, p. 388, A-E.)

77/397 Great Britain *Psychological Aspects of Colour Measurement.* (H. J. Eysenck, Nature, Vol. 147, No. 3,735, 31/5/41, pp. 682-683.)

77/398 U.S.A. ... *On the Technique of Forecasting Low Ceiling and Fog.* (J. J. George, J. Aeron. Sci., Vol. 8, No. 6, April, 1941, pp. 236-241.) (Abstract available.)

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77/399 Great Britain *The Uses of Psychology in War Time.* (C. S. Myers, Nature, Vol. 147, No. 3,732, 10/5/41, pp. 564-566.)

77/400 U.S.A. ... *N.A.C.A. Index of Reports on Aeronautical Research up to September,* 1940. (N.A.C.A. Index of Reports, Sept., 1940, pp. 1-24.) (Abstract available.)

77/401 Great Britain *A Mechanical Method for Graphical Solution of Polynomials.* (S. L. Brown and L. L. Wheeler, J. of Frank. Inst., Vol. 231, No. 3, March, 1941, pp. 223-234.) (Abstract available.)

77/402 U.S.A. ... *Control of Paper Expansion in Multicolour Lithography.* (J. of Franklin Inst., Vol. 231, No. 4, April, 1941, pp. 386-387.)

77/403 Great Britain *The I. Ae. S. Annual Meeting.* (A. Klemin, Aircraft Engineering, Vol. 13, No. 147, May, 1941, pp. 123-127 and 130.)

77/404 U.S.S.R. ... *Experience in the Rapid Planning of a Factory.* (B. V. Yunov, Aviation Industry, No. 2, Jan., 1941, pp. 8-10.)

77/405 Great Britain *The Electric Battery Vehicle.* (J. Steel, Engineer, Vol. 171, No. 4,454, 23/5/41, p. 335.)

77/406 Great Britain *Research in Canada.* (A. G. L. McNaughton, Nature, Vol. 147, No. 3,734, 24/5/41, pp. 626-630.)

77/407 U.S.A. ... *Hydro-Pneumatic Tyre (Water Filled).* (Autom. Ind., Vol. 84, No. 6, 15/3/41, p. 348.)

77/408 Great Britain *Training Schools in American Firms.* (Aeroplane, Vol. 60, No. 1,565, 23/5/41, p. 578.)

77/409 U.S.A. ... *U.S.A. Production,* 1940. (Inter. Avia., No. 748-749, 6/2/41, pp. 14-15.)

77/410 U.S.A. ... *U.S.A. Export Production.* (Inter. Avia., No. 752, 27/2/41, p. 12.)

77/411 U.S.A. ... *N.A.C.A. Annual Report for* 1940. (Inter. Avia., No. 753, 6/3/41, p. 5-6.)

77/412 U.S.A. ... *Airplane Patent Digest, Vol. 2, No. 23, Dec. 14th,* 1940. (Particulars of 30 patents in this number range 2,223,508 and 2,224,732.)

77/413 Great Britain "*Bristol Aero Engine*" *Dept. Tech. Abstracts and Informations.* (Vol. 5, No. 22, June 3rd, 1941.)

77/414 U.S.A. ... *Recent Developments of the Pease Anthony (Cyclonic) Gas Scrubber.* (R. V. Kleinschmidt and A. W. Anthony, Trans. A.S.M.E., Vol. 63, No. 4, May, 1941, pp. 349-357.)

77/415 Great Britain "*Bristol*" *Aero Engine Dept. Tech. Abs. and Information.* (Vol. 5, No.23, June 10th, 1941.)

77/416 U.S.A. ... *A Study of the Development of Skill during Performance of a Factory Operation.* (R. M. Barnes and J. S. Perkins, Trans. A.S.M.E., Vol. 63, No. 4, May, 1941, pp. 319-328.) (Abstract available.)

PHOTOGRAPHY.

77/417 Great Britain *Airgraph Mail Service Micro Photographs.* (Flight, Vol. 39, No. 1,689, 8/5/41, p. 332.)

77/418 U.S.S.R. ... *Device for Connecting up Short Sections of Aerial Photo Film.* (K. N. Sacharov, Air Fleet News, Vol. 23, No. 3, March, 1941, pp. 263-264.)

77/419 Canada ... *Electrolytic Transfer Process for Reproducing Work Templates. (Alternative to photo loft process in case of 1 × 1 reproduction.)* Canadian Aviation, Vol. 63, No. 4, April, 1941, pp. 54-58.)

77/420 Great Britain *Barcro System of Duplicating Drawings, etc.* (Aircraft Production, Vol. 3, No. 32, June, 1941, pp. 207-208.)

77/421 Great Britain *Electrolytic Copying of Templates.* (Aircraft Production, Vol. 3, No. 32, June, 1941, p. 215.)

SOUND, LIGHT AND HEAT.

77/422 Great Britain *Methods of Calculating the Frequencies of Overtones.* (W. J. Duncan and D. D. Lindsay, R. and M.'s (A.R.C. Tech. Report) No. 1,888.)

77/423 U.S.A. ... *Effect of Temperature on Coiled Steel Springs under Various Loadings.* (F. P. Zimmerli, Trans. A.S.M.E., Vol. 63, No. 4, May, 1941, pp. 363-368.) (Abstract available.)

WIRELESS AND ELECTRICITY.

77/424 Great Britain *Factors in the Design of Electric Heating Elements.* (R. Jessel, J. Inst. Elect. Eng., Vol. 88, Part 2, No. 2, April, 1941, pp. 93-102.)

77/425 U.S.S.R. ... *Allowing for Time when Taking Radio Bearings.* (M. E. Gorshkov, Air Fleet News, Vol. 223, No. 3, March, 1941, pp. 235-236.)

77/426 Great Britain *Anti-Static Devices for Aircraft.* (Aeroplane, Vol. 60, No. 1,564, 16/5/41, p. 557-559.)

77/427 Germany ... *The Effect of Atmospherics on Wireless Reception on Aircraft.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 113-114.)

77/428 U.S.A. ... *Determination of the Average Life of Vacuum Tubes.* (D. K. Gannett, Bell Laboratories Record, Vol. 18, No. 12, Aug., 1940, pp. 378-382.) (Abstract available.)

77/429 U.S.S.R. ... *Preparation of a Map for Radio Navigation.* (M. F. Gorshkov, Air Fleet News, Vol. 23, No. 1, Jan., 1941, pp. 46-48.)

77/430 U.S.A. ... *Harvey Directional Control.* (Inter. Avia., No. 753, 6/3/41, p. 6.) (Abstract available.)

77/431 Great Britain *A New Use for X-Rays in Industry.* (Woods and Kenner, Electronics, April, 1941, pp. 29-31.) (Met. Vick. Tech. News Bull., No. 763, 21/5/41, p. 13.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
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(Prepared by R.T.P.)

No. 93. AUGUST, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

Requests from scientific and technical staffs for further information or translations should be addressed to R.T.P.3, Ministry of Aircraft Production.

Only a limited number of the articles quoted from foreign journals are translated and usually only the *original* can be supplied on loan. If, however, translation is required, application should be made in writing to R.T.P.3, the requests being considered in accordance with existing facilities.

NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automobile Industries.
Autom. Tech. Zeit. ...	Automobile Technische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Electroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.

J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Verroffent (Siemens)	Veroffentlichungen aus dem Gebiete der Nachrichtentechnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatschefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für Das Gesamte Schiess und Sprengstoffwessen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Tactics of Photographic Reconnaissance in the Defence Zone. (P. I. Russ, Air Fleet News, U.S.S.R., Vol. 23, No. 2, Feb., 1941, pp. 117-119.) (93/1 U.S.S.R.)

The most valuable form of aerial reconnaissance is photography, with subsequent evaluation (interpretation) of the results.

During an advance, aerial (photographic) reconnaissance of the enemy defence zone is of the utmost importance. Photographic reconnaissance material will be required by all units down to the tank company and artillery battery. This will call for a great deal of hard and detailed work by the photographic reconnaissance units.

An aircraft on photographic reconnaissance must carry out its flight under pre-determined conditions, which may not be varied. The altitude is determined by the required scale of the reproduction, and the focal length of the camera used. The altitude can be calculated by $H = f.Mc$, wherein H = altitude, f = focal length of the camera, Mc = required scale.

Sharpness of definition depends on the time of exposure which must not produce a corresponding displacement of the target on the film by more than 0.1 mm., the maximum exposure time is thus given by

$$E_{max} = \frac{M}{100\,W}$$

where W = aircraft speed in m./sec

Enemy fighter aircraft may be standing ready for interception on the forward aerodromes, or in ambush. They must be driven off, or their attention distracted to another area. This curtails fighter support. Alternatively, the reconnaissance may be effected by surprise.

Enemy anti-aircraft artillery may be put out of action by dive-bombing. Advantage may also be taken of the pause of about three to five minutes every eight to ten minutes, when the guns have to stop firing in order to cool the barrels. Finally, photographs may be taken with a telephotographic lens from a safe altitude.

Aerial photographic reconnaissance requires the utmost co-operation between local headquarters of the air force in the attack zone and the staffs of the ground troop.

Tactical Requirements in Fighter Design. (M. P. Stroyeu, Aeronautical Engineering, U.S.S.R., Vol. 17, No. 12, Dec., 1940, pp. 18-24.) (93/2 U.S.S.R.)

The science of tactics (" methods of combat ") depends on the quality of men and machines. Technical development is not static, and at any given moment bears potential possibilities of progress to a higher plane. It is the business of tactical science to examine these possibilities, and incorporate their fulfilment in the design of new weapons—in the present case, fighter aircraft:—

CONCLUSIONS.

1. Fighter aircraft of all types should be designed exclusively for aerial combat; any other employment should be purely subsidiary.
2. *Three* standard fighter types are necessary; single-seater, high speed and manœuvrable monoplanes, and long-range two-seater twin-engined machines.
3. For aerial combat it would be desirable to replace the existing single-seater fighters by a pusher-screw type, subject to suitable technical development of this arrangement.
4. Particular attention is desirable to the further development of flaps and similar controls so as to combine the qualities of manœuvrability and high speed in a single type of fighter.
5. Night fighters and sub-stratosphere types can be obtained by adaptation of existing basic types.

New Air Force Tactics in the Present War. (N. Juravlev, Aeroplane, U.S.S.R., Vol. 18, No. 1, Jan., 1941, pp. 31-34.) (93/3 U.S.S.R.)

All opinions on the tactics, methods, and objectives of aerial warfare are now undergoing the test of actual war; some opinions will be found maintained, others refuted, and others requiring modification. In any case, all tactical views and principles have become considerably more stabilized and concrete than in times of peace.

From a careful examination of German aerial tactics during the present war, the following conclusions result:

The air arm in its present development has become a mighty and effective weapon, capable of co-operating effectively with the sea and land forces, but able also to carry out independent strategical tasks (sea blockade, destruction of enemy economic resources) which can have a decisive influence on the course of the war.

Experience shows that such independent operations require ample resources, and *time*. The former assumptions of the ease with which " smashing blows " could be delivered on industrial centres need considerable revision.

Such operations, under present conditions, can be performed only at night. The success of night operations depends principally on the training of air-crews.

In daylight operations the most suitable aircraft type is the twin-engined, two-seater, fighter-bomber. Daylight bombing is limited in range by the endurance of the indispensable fighter escort.

The most effective interceptor is the *cannon* armed fighter.

The only really new tactical development in the present war is the use by the Germans of two-seater fighter-bombers for the attack on industrial targets.

Echo Sounder for Air Defence. (Inter. Avia., No. 764-765, 19/5/41, pp. 19-20.) (93/4 U.S.A.)

From publications by the U.S. Patent Office the plans are disclosed of a novel device for the detection of the position of aeroplanes at night or in bad visibility. The instrument appears to be based on principles similar to those employed in the Absolute Altimeter developed by the Western Electric Corp., which, with the aid of two dipole antennas, transmits radio waves and again receives part of the waves reflected from the ground, ultimately determining the absolute distance between the ground surface and the aeroplane from the elapsed period of time. However, while the waves transmitted by the transmitter of the altimeter spread over a hemispherical space below the aeroplane, the ultra-frequency waves of the aircraft locator (measuring about 50 centimetres) are focussed into beams by parabolic reflectors. When, directed into space, the beam encounters an aeroplane, the location and the altitude of the machine can be determined from the direction and time differential of the reflected wave; flying course and flying speed of the aeroplane are calculated from successive measurements. By rapid to and fro motions of the transmitted beam on the principle of the television apparatus, a certain air space can be constantly surveyed and the flying course of the aeroplane made visible by controlling a cathode ray. A distinction between attacking and defending aeroplanes is naturally not possible.

Bell Sound Detector. (Inter. Avia, No. 764-765, 19/5/41, p. 20.) (93/5 U.S.A.)

The Bell Telephone Laboratories Inc., of New York, have taken out U.S. patent No. 2,225,312 to protect a new type of sound detector for ground defences. The instrument consists of a cluster of parallel tubes varying in diameter and length, the open ends of which form a spiral. A completed model comprised 49 such tubes. The length of the longest tube corresponds to the wave-length of the lowest sound frequency to be detected. The sensitivity of the instrument to sound waves not exactly parallel to the tubes is very small and thus permits the accurate determination of the direction of the sound.

Dive Bombing (Attack Bombing) in Sea Warfare. (D. U. Marchukoo, Air Fleet News, U.S.S.R., Vol. 23, No. 1, Jan., 1941, pp. 17-22.) (93/6 U.S.S.R.)

The particular features of maritime targets—mobility, manœuvrability, small dimensions—entail a totally different technique of attack, which favours the use of attack-bomber types. Suitable types are instanced—the Japanese "96" aircraft, with a 850 h.p. Wright-Cyclone engine: top speed 300 km./hr., ceiling 7,000 m., range 2,000 km., crew of three, armament 5 machine guns, and 500 kilos. bomb load. Also the American "Vought 90," designed as a fleet fighter.

The Germans have used "Messerschmidt 110," "Dornier 17," "Heinkel He 111K," and "Junkers 87" types. The ideal naval attack bomber would be a machine with 400 km. top speed, 4-b machine guns or 2 m.g.'s and 2 cannon guns, possibly in turrets; bomb-chutes for a total of 400 kilos. small bombs, from 1 to 10 kilos. each; wing bombs up to 50 kilos., 8-10 in number. The machine must be able to alight on the water and remain afloat at least 2-3 hours.

Any type of fighter, fighter-bomber, or attack-bomber can, however, be used against naval targets provided the aircraft crews are suitably trained.

Winter Camouflage of Aircraft. (S. Y. Miroutsev, Air Fleet News, U.S.S.R., Vol. 23, No. 1, Jan., 1941, pp. 37-40.) (93/7 U.S.S.R.)

The article gives detailed instructions for the camouflage of aircraft on the ground under winter conditions in various surroundings; woods, bushes, open fields, built-up areas, burnt and ruined buildings, etc.

In addition, care should be taken in selecting positions for grounded aircraft, to prevent disclosure by the appearance of tracks, discoloured or trampled snow, shadows thrown by the aircraft or reflection or glare produced by it. Aircraft should preferably be disposed to take advantage of natural features, roads, buildings, etc., so as to conceal all traces of activity around them.

Instructions are given for the design and construction of building mock-ups, camouflage screens, sheets, etc. for the purpose of screening the aircraft.

The Servicing of Aircraft Weapons for Firing at High Altitudes. (H. Kumpiak, Air Fleet News, U.S.S.R., Vol. 23, No. 1, Jan., 1941, pp. 67-68.) (93/8 U.S.S.R.)

Automatically operated machine or cannon guns for action at high altitudes require special preparation, either by the use of heaters or by the use of cold resistant lubricants.

Heaters may be electric, or use exhaust gases, and serve to maintain a suitable temperature for unhindered operation of the automatic weapon. They are fitted on or around the breech mechanism and thus impair the accessibility of the gun. Electric heaters are essential for movable weapons and turret guns. Unfortunately the extra electrical energy required is not always easily provided for. Exhaust-gas heaters can only be used for fixed weapons.

The adoption of a lubricant of low congealing point appears the most suitable means of assuring the operation of automatic weapons at high altitudes. The lubricant should be kept in sealed drums until used, and the weapon thoroughly cleaned and dried before lubricating. All excess of lubricant should be avoided.

(No details of the oil specification are given.)

Aircraft versus Submarine. (A. Ignatier, Aeroplane, U.S.S.R., Vol. 18, No. 5, May, 1941, pp. 25-27.) (93/9 U.S.S.R.)

After giving details of the activities of German submarines in the Great War, and the methods of aerial warfare used to combat them, the author passes to a consideration of the interaction of aircraft and submarine forces under present conditions.

The submarine presents little danger to the aircraft. The aircraft, on the other hand, is specifically an offensive weapon. Its advantages in anti-submarine warfare are: the possibility of mass attack, the suddenness of the attack, and co-operation with surface craft.

Aircraft are an effective weapon against under-water craft on the surface, and unable to submerge. The submarine must then rely only on increased aerial observation, co-operation with defending aircraft, and camouflage to lower the visibility of the submarine when surfacing.

Co-operation between aircraft and submarines should be both tactical and operational. Simultaneous action should not be sought; co-operation resolves itself into reconnaissance, exchange of information, and individual attack on the target as opportunity presents itself.

The German attempt to blockade the British Isles in the "Battle of the Atlantic" affords the best example of operational co-operation of aircraft and submarine, *e.g.*, by aerial attacks on ports and bases, after the submarines have spotted and reported the approaching convoys; air attack on industrial and production centres, to render the country more dependent on imported materials, which then are exposed to submarine attack en route. The air forces carry out the "close blockade," and submarine forces the "long-range blockade."

Whether Britain's armed forces can cope with the menace, depends primarily on her ability to secure preponderance of aerial and anti-submarine forces. In any case, this battle for the lines of communication is the principal feature of the war at present.

Tactical Requirements in Fighter Design. (Y. P. Nikolaev, Aeronautical Engineering, U.S.S.R., Vol. 15, No. 3, May, 1941, pp. 56-58.) (93/10 U.S.S.R.)

The author's review refer to a previous article under the same title by M. P. Stroyev ("Aeron. Eng." U.S.S.R., Vol. 14, No. 12, Dec., 1940—R.T.P. notice 26,763). The following conclusions are put forward:—

1. The twin-engined, single-seater fighter, particularly with air-cooled engines, has considerable tactical advantages by comparison with the single-engined fighter.
2. In aerial combat with single-engined fighters the twin-engined machine will have the following advantages:—speed, vertical manœuvrability, service ceiling, armament, and field of vision from the cockpit:
3. The twin-engined machine is better adapted for bomber interception, particularly on account of its heavier armament. The same feature renders it suitable for anti-tank operations.
4. The subsidiary tactical possibilities of the twin-engined machine are far greater.

Aircraft Armour—Production Speed Up. (Scientific American, Vol. 165, No. 2, Aug., 1941, p. 95.) (93/11 U.S.A.)

The severe limitations on airplane weight require that the gauge of the armour plate be as light as possible, consistent with effective resistance to the projectile. Thus, airplane armour ranges up to 44 inches by 44 inches by $1\frac{1}{2}$ inches, most of it being in $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ of an inch in thickness. Armour plate is essentially a nickel-alloy steel. It must be exceedingly hard on the exposed side; tough but more ductile on the interior side.

The requisite hardness is obtained by carburisation of the exposed surface. As much as 50 hours may be required for a complete heat for $\frac{1}{4}$ inch plate. In the new Breeze process, three heats can be carried out in 24 hours. The carburising treatment is accomplished with a liquid salt bath in an electric furnace. This equipment enables the work to be charged and removed quickly, brings the plates up to the desired temperature quickly and makes accurate control of the temperature possible.

Contribution to the Theory of Wind Tunnel Turbulence. (W. Tollmien and M. Schafer, Z.A.M.M., Vol. 21, No. 1, Feb., 1941, pp. 1-17.) (93/12 Germany.)

After a review of previous research work, a mathematical model of the wind tunnel turbulence is obtained by linearizing the hydrodynamic equations, without making the usual assumption of isotropic turbulence. A new integration theory is developed for the evaluation of the problem which results in a separation of the flow into a potential and a diffusion constituent. [The possibility of such a sub-division was first mentioned by the senior author when taking part in a discussion at the 5th Int. Congress of Applied Mechanics 1938.]

Some mean values for both types of flow taken separately are determined and methods are indicated for obtaining similar values for the constituent.

The Effect of Nozzle and Collector on Resistance Measurement in the Free Jet Wind Tunnel. (D. Kucheman and F. Vardrey, Z.A.M.M., Vol. 21, No. 1, Feb., 1941, pp. 17-31.) (93/13 Germany.)

The author calculates the 3 dimensional potential flow round semi infinite bodies and source-sink bodies in a circular tunnel consisting of nozzle, collector

and free jet. In order to satisfy the boundary conditions the solid walls are provided with vortices. The integral equation determining their distributions is of the second kind and can be solved numerically by iteration. Once the source and vortex distribution is known, the flow round semi-infinite bodies and source-sink bodies of various thickness and in varying position relative to the nozzle, can be calculated and the force due to the additional velocities determined. The author shows that whilst the velocity distribution in the neighbourhood of the body may be appreciably affected by the presence of nozzzle, collector and jet confines, the effect on the resistance measurement is negligibly small.

Potential Flow Through Centrifugal Pumps and Turbines. (E. Sörensen, Z.A.M.M., Vol. 7, No. 2, April, 1927.) (R.T.P. Translation T.M. 973.) (93/14 Germany.)

The method of conformal transformation has only been applied to the potential flow about bodies in rotation to a limited extent. The main reason is the fact that the boundary conditions are not maintained after the transformation. In the case of pure translation this difficulty can be overcome by considering relative inertia only. This method is not applicable to rotary motions since the relative motion is no longer irrotational. The author, in applying the conformal transformation, follows *Spannhake* (Z.A.M.M., Vol. 5, No. 6, 1925, pp. 481/484) in taking the absolute flow as a basis of his investigations. Only two-dimensional flow is considered. Whilst, however, Spannhake's solution for the complex potential depends on finding the coefficients of a Fourier series (which for this purpose must be rapidly converging, and may often present difficulties), the author gives the potential in the form of a definite integral of the same type as first discussed by *Walther* (Trans. C.A.H.I., Moscow 1926). The case when the pump blades are logarithmic spirals is discussed in detail, use being made of a transformation function given by König (Z.A.M.M., Vol. 2, No. 6, 1922).

Of interest is the variation of angular velocity (w'_0) for shock-free entry with a number of blades n. With increase of n the angular velocity approaches the limiting value w_0 given by the Euler formula.

This is illustrated in the following table:

n	w'_0/w_0
1	.02
2	.23
3	.43
6	.72
12	.82
24	.92
∞	1.0

(For the effect of entry shock on the characteristics, see *F. Riegel & J. Weber*, Z.A.M.M., Vol. 12, Feb. 1941, pp. 63-69, R.T.P. Translation No. 1245).

Numerical Calculation of the Neutral Point of a Wing. (E. Kuhle, L.F.F., Vol. 17, No. 9, 20/9/40, pp. 257-266.) (Available as R.T.P. Translation No. 1,234.) (93/15 Germany.)

The neutral point of a wing section is defined as the point about which the longitudinal moment is independent of the incidence. Provided such a point exists for each end section, the author shows for all practical wing shapes, that a neutral point exists for the wing as a whole. The position of this point can be found provided the lift distribution over the span is known. An approximate method for calculating this distribution is described, which is of sufficient accuracy for the purpose in view, provided that no extensive cut-outs in the wing surface exist. This is illustrated by means of two worked-out examples

and the good agreement with experiment indicates that an accurate knowledge of the lift distribution is not generally required.

Since the fuselage as such has no neutral point, the combination of wing and body will only have such a characteristic if the wing interference masks the body effect. In general, there will be a series of neutral points, each of which applies to a limited range of c_a values.

Explosive Rivets for the Repair of Aircraft at Advanced Air Bases. (Air Fleet News, U.S.S.R., Vol. 23, No. 2, Feb., 1941.) (93/16 U.S.S.R.)

The author summarises an article in the German periodical " Werkstatt und Betriel " for November, 1940, dealing with the system of explosive rivetting developed by the Heinkel works.

The method is particularly useful at advanced air bases for patching bullet holes in aircraft, where the hole is accessible only from one side. The hole is cut away to a suitable circular or rectangular shape, a patch laid on, and temporarily secured by a special form of hook-bolt with a securing nut. The rivets are then inserted and exploded in the usual way. It is important to select the right length of rivet, and a special form of micrometer gauge is therefore used to measure the thickness of the plates and patch to be joined in place.

It is estimated that this method speeds up repairs some seven to ten times.

A short note on the same German article is also given in " Aviation Industry," U.S.S.R., Vol. II, No. 3, January, 1934.

Notes on the Maintenance of Aircraft in Winter. (V. G. Alexandrov, Civil Aviation, U.S.S.R., Vol. 2, No. 1, January, 1941.) (93/17 U.S.S.R.)

These notes deal with the effect of low temperatures on materials of construction and equipment. Pine and spruce, frozen in a damp condition, lose up to 15-30 per cent. of their strength. Ice crystals forming between the fibres of the wood, dimish its strength and cause splitting. Expansion at freezing also weakens butts, joints, and connections. Upon thawing, the resultant moisture favours infestation with moulds. In winter, therefore, aircraft of *wooden* construction, or wooden parts of aircraft, should be protected from moisture as far as possible, kept dry and well ventilated, with painted or varnished surfaces intact, and carefully dried out after getting wet with rain or snow.

Aircraft and Metal Parts.

The use of materials with different coefficients of expansion and heat transmission in *metal* causes internal stresses with change in temperature, leading to snapping of rivets, leakage of seams, and bursting of skin plating. Moisture penetrating inside also gives rise to corrosion. Rivetted and welded joints should therefore be carefully inspected in winter for failures arising from such temperature effects. Lubrication also needs attention; some oils thicken to such an extent at temperatures between $-10°$ and $-20°$, as to lose all lubricating properties. For prevention of corrosion, aircraft should be thoroughly dried, both inside and out, after being exposed to rain or snow. All bare places should be specially treated with anti-corrosives, as the usual painting is generally insufficient under winter conditions. Parts exposed to ice accretion should be thawed out with rags dipped in hot water (not over 50-60°C.) and rubbed dry. *Rubber* preserves its normal properties down to a temperature of $-25°$ to $-40°$C. Below this it loses its elasticity and resilience powers. On stony or gravelly ground tyre covers and tubes are often punctured owing to such loss of elasticity at low temperatures, and runways of this type should not be swept of snow. Iced or frozen surfaces may be lightly sanded or treated with chopped hay or straw, frozen in place by means of the aerodrome water-cart. If parked in the open, planks, twigs or straw should be placed under all landing wheels, skids or runners, and wheels kept covered.

Rubber parts should be protected from splashing by oil, petrol or paraffin, which softens the rubber. Splashes should be washed off only with warm soapy water.

Engines require special attention when starting up in winter. The cooling system should be filled with water at 70-90°C., and the engine warmly covered. The first 10-15 litres of cooling water should be at a lower temperature (50-60°) to prevent cracks in the radiator. All drain cocks should be left open until the water leaves them at approximately filling temperature. When filling, attention should be paid to any frozen pockets in the radiator. If such are found, filling should be stopped, and the frozen places thawed by rags dipped in hot water, or by hot air from the heating above. If left out in the cold, the water should be drained off as soon as its temperature falls below 30-40°C.; and in order to prevent fractures in the radiator or cylinder jackets the drain cocks must be left open. *Anti-freeze* compound contracts at low temperatures and therefore does not require to be drained off. To assist starting at temperatures of about $-8°$ to $-10°$C., the anti-freeze or the engine can be warmed up. On heating, anti-freeze expands more than water, and a smaller quantity should therefore be used in filling the radiator.

Air-cooled engines can be easily started if warmed up by the heating stove, filled with hot oil at 80-90°C., and the sparking plugs well cleaned from oil and dirt. Flooding the engine with petrol, or using low vapour pressure fuel will impede starting up. The engine should always be swung over some 8-10 revs. by hand before switching on.

The engine should never be started at very low temperatures without being first warmed up, as otherwise there is a grave risk of damage to the auxiliary drives.

Determination of the Optimum Flight Conditions for Aircraft PS-84. (L. S. Konikor, Civil Aviation, U.S.S.R., Vol. 11, No. 5, May, 1941, pp. 3-4.) (93/18 U.S.S.R.)

Experiments made on the Leningrad-Moscow air route to determine the optimum conditions of flight are described.

From the recorded wind strength, the speed-increment due to wind $(w-v)$ was determined and added to the speed-increment due to altitude (Δv). The optimum altitude was assumed to be that at which the algebraic sum of $\Delta v + (w-v)$ had the greatest positive value.

For the PS-84 aircraft, however, this method of estimating optimum flying height led to considerable wastage of fuel, amounting in some cases to more than 200 kg. above calculated consumption (0.92 kg. per kilometre).

It was found that pilots were in the habit of flying at recommended cruising output of 550 h.p. with a speed by instrument of 250-260 km./hour and about 450 h.p. output, 240 km./hr. speed by instrument and 600 m.m. supercharge, 700 m.m. supercharge. Loss of control was apparently feared at lower speeds.

Tests flights at reduced output were therefore made to check this. At 400- the excess fuel consumption was immediately reduced to 16 kg. for the trip (Leningrad-Moscow, 617 km.) with a following wind, and 22 kg. with a contrary wind. Finding that the aircraft still arrived at destination ahead of schedule (with a following wind), instrument speed was reduced to 235 km./hr. and supercharge to 580 m.m. This resulted in a saving in fuel of 25 kg. over the calculated standard.

The ultimate result of these experimental round trips with the PS-84 was as follows:—

1. Theoretical fuel consumption of 0.92 kg./hr. at a mean indicated speed 265 km./hr. could be maintained with a following, but not a contrary, wind.

2. It is recommended that the cruising h.p. be reduced to 420-450 h.p. knowing the wind at optimum altitude, the indicated air speed for schedule follows. This in turn settles the h.p. more exactly.

3. Optimum flying height should be determined not only by the maximum $\Delta v + (w - v)$ but also allowing for increased fuel consumption in climb. Special curves are recommended for each route, from which pilots can obtain the optimum altitude in relation to maximum speed and minimum fuel consumption.

Airscrews for High-Speed Aircraft with High-Power Engines. (B. N. Egorov, Aeronautical Engineering, U.S.S.R., Vol. 15, No. 3, March, 1941, pp. 11-27.) (93/19 U.S.S.R.)

The available information on the problem can be summarised in the following points:—

1. The tip-speed of the airscrew should not exceed 0.90-0.95 of the velocity of sound.
2. High power engines require airscrews of large diameter, with corresponding reduction of the engine revolutions.
3. Increased airscrew diameter implies increased weight, and increased weight/power ratio. To reduce weight, many-bladed airscrews should be used, despite the consequent drop in efficiency.
4. High-power engines for fighter aircraft will require many-bladed airscrews on account of limitations of weight and diameter. This will, however, cause difficulty in take-off and landing.
5. For single-engined, high-powered aircraft, co-axial airscrews are necessary to reduce the reaction moments.
6. The increased weight of the airscrew for high powers suggests intensive research on the construction of airscrews of light alloys, or with hollow blades, and measures against blade-vibration.

Investigations were conducted for engine powers of 1,000, 1,500, 2,500 4,000, 6,000, and 8,000 h.p. at a standard altitude of 6,000 metres, for n/Δ ratios of 1,860 2,790, 4,650, 7,470, 10,150, and 17,850 (Δ = relative density), airspeeds of 500, 650, 800, and 950 km./hr., and airscrew diameters of 2.5, 3.0, 4.0, 5.0 and 6.0 metres, with 3, 4, and 6 blades. To elucidate the influence of the revolution speed and tip speed on efficiency, calculations were also carried out for Mach numbers of 0.8, 0.9, 1.0, 1.1, and 1.2.

The conclusions from these researches are as follows:—

1. With increase of flying speed to 650-700 km./hr., the efficiency increases for constant diameter, number of blades, and engine power; at higher speeds efficiency again falls.
2. Up to airspeeds of 850 km./hr. the tip speed should not exceed 0.9-0.95 of the velocity of sound. The top speed may equal the velocity of sound for airspeeds above 900 km./hr.
3. Increasing the engine power at constant airscrew diameter and airspeed reduces efficiency, the reduction being less with increasing diameter.
4. To allow maximum efficiency of airscrews for powers from 2,000 h.p. upwards, large diameters (up to 6 m.) with corresponding reduction of the revolution speed will be required.
5. Up to 1,500 h.p., four- and six-bladed airscrews are unsuitable on account of increased weight.
6. For powers of 2,000 h.p. and over, many-bladed airscrews are preferable in order to reduce weight and diameter.
7. The use of co-axial airscrews permits of reducing the diameter and reactive moment. The efficiency can also be somewhat increased by the elimination of twist in the slip-stream.

8. The considerable increase in weight caused by the increase in diameter and number of blades demands research on the lighter construction of airscrews.

9. The reduction ratio (of airscrew revolutions) calculated by Caldwell's method (Journal of Aeronautical Science, Dec. 1937) for powers of 1,000 to 1,600 h.p. at an altitude of 6,000 m., corresponds in practice with the reduction obtained by calculation according to the optimum distribution of circulation.

10. For engines exceeding 2,500 h.p. at an altitude of 6,000 m. (*i.e.* $\frac{n}{\Delta} > 4{,}650$) the revolution speeds, varying between 600 and 1,200 r.p.m. depending on diameter of airscrew recommended in this article will be suitable.

A New Wind Tunnel Balance for Model Airscrew Experiments. (A. Eula, Atto di Guidonia, No. 44, 20/2/41,) (93/20 Italy.)

The balance enables the usual thrust and torque measurements to be made on model airscrews with a diameter of the order of 1 m. rotating at speeds up to 3,000 r.p.m. The balance is intended for use in open jet wind tunnels with a diameter of the order of 2 m. Of main interest is the 3-phase electric motor for operating the screw. This has been designed and constructed by the Goettingen Laboratory (Germany), and delivers a maximum of 100 h.p. at 30,000 r.p.m. for a total weight of 70 kg., the external dimensions being approximately 18 cm. diameter, 60 cm. length. For the Guidonia Installation, the periodicity has been reduced from 500 to a maximum of 100 cycles/sec., with the result that the maximum h.p. is now of the order of 20 at 6,000 r.p.m. A 2/1 reduction gear between airscrew and motor reduces the speed of the former to a maximum of 3,000 r.p.m. Speed and power control are obtained by means of the well known Ward Leonard system (control of frequency of a/c. supply).

The propeller torque is measured directly from the reaction of the motor casing and can be estimated to ± 10 gm. at a leverage of 20 cm. The thrust is obtained from the horizontal pull on the motor, with an error of ± 20 gm.

By rotating the whole suspension about the wind tunnel axis, the lateral force acting on the propeller due to oblique incidence can be obtained with an accuracy of ± 50 gm. For measuring propeller characteristics in free air, the motor is enclosed in a fixed stream line casing of considerable length, the propeller hub being shielded by a fixed nose piece of suitable shape.

The clearance between motor and casing is very small and in view of the restricted diameter of the former it is held that the flow approximates very closely to free air conditions.

If the effect of engine nacelles has to be investigated, models of the latter are mounted directly on the motor casing and the motor casing and the resultant torque and thrust measurements indicate the amount of body interference.

Model airscrew experiments necessarily suffer from the defect that both the Reynolds and Mach numbers differ appreciably from those occurring in full scale flight. The author, however, points out that similar corrections have also to be applied to full scale propeller tests on the ground, since the air speeds of the large wind tunnels so far constructed in which these experiments are carried out are all considerably below flying speeds. In view of the reduced cost and saving in time, experiments with models of the dimensions discussed above seem well worth while.

Parachutes and Their Manufacture. (G. Sedlwayr, Luftwissen, Vol. 8, No. 5, May, 1941, pp. 146-150.) (93/21 Germany.)

Some details of the manufacture of the standard parachute as employed by the Luftwaffe for their aircrews are given. The canopy requires about 40 m.^{2} of silk fabric and the packing requires benches 8 m. long. The cutting out

is carried out on 20 m. benches by means of electrical machines, several hundred parts of the same shape being cut simultaneously. The complete canopy consists of 96 parts and great care is taken in the lay-out of the pattern to reduce wastage of the expensive material to a minimum. The sewing together of the parts is carried out by means of special 4-needle sewing machines, the seams being checked by means of transmitted light. A series of 13 photographs show details of the manufacture and method of packing. Female labour is extensively made use of. The main parachute is controlled by the release of a small pilot parachuted and generally is unfolded only after the speed of descent has dropped to about 200 km./hr. This reduces the opening shock on the body of the parachutist. In several emergency cases, however, the parachute had to be operated at speeds as high as 600 km./hr. without ill effect to the parachutist. The landing speed is normally of the order of 6-7 m./sec. If the parachute is used to drop supplies etc. greater landing speeds are permissible and a cheaper and more " transparent " fabric can be employed. It is obvious that such parachutes must be positively controlled either by being attached to the aircraft by means of a release line or fitted with some clockwork mechanism which will open the canopy after a certain time lag.

Operation of Aircraft Fuel System at High Altitudes. (M. P. Fokin, Air Fleet News, U.S.S.R., Vol. 23, No. 5, May, 1941, pp. 445-447.) (93/22 U.S.S.R.)

Irregularities in the running of aircraft engines at high altitudes are due to the formation of " vapour locks " in the fuel system.

Such vapour locks are produced by:—

1. Presence of high-volatility components in the fuel which separate at high altitudes owing to the reduced atmospheric pressure.
2. Pressure of dissolved air in the fuel which segregates under the same conditions.
3. Heating of the fuel in certain parts of the system, promoting volatilization of the fuel.

The proportion of high volatile fractions in the petrol can be determined by the vapour tension, the normal figure being 360 m.m. Hg. at 38°C. The higher the tension the greater the risk of vapour locks.

The fuel should therefore be kept as cool as possible in ground storage, protected both there and in the fuel tanks from the heat of the sun. A vapour tension of 270-330 m.m. Hg. at 38°C. should ensure normal running at altitude.

Operation of the Cooling System of a High Altitude Aircraft. (Air Fleet News, U.S.S.R., Vol. 23, No. 4, April, 1941, pp. 340-344.) (93/24 U.S.S.R.)

At altitude, either the designed radiator surface will be insufficient, causing overheating of the engines, or it will be excessive, causing over-cooling. This is due to the pressure and temperature drop at high altitudes. The boiling point of the coolant will also be reduced, and special measures will be required for its maintenance.

The usual remedy is to employ closed circuit cooling, permitting the coolant to be kept at a pressure above the atmospheric, and thus at a higher boiling point. The controlling element in such a system is a reducing or safety valve at the highest point of the circuit.

The necessary excess pressure can be determined by the formulæ

$$P_x = P_o - P_h$$

where P_x = excess pressure in the cooling system, P_o = atmospheric pressure at ground level, P_h = atmospheric pressure at altitude.

With change in altitude the relief valve of the closed circuit system will thus require spring tension and special precautions must be taken for the case of rapid loss of height (long glides or dive bombing).

The increased pressure in the system will call for increased care in construction and maintenance in order to ensure the structural strength of all components and prevent breakdown.

The relief valve, being the most vulnerable point of the closed circuit cooling system, requires special attention in regard to construction, operation and maintenance.

Design Features of D.B. 601A Aircraft Engine. (Autom. Ind., Vol. 84, No. 12, 15/6/41, pp. 616-617.) (93/23 U.S.A.)

The following comparisons of the D. 0601 with other representative water-cooled engines of similar power is of interest.

Comparison of Engine Specifications and Performance.

1. Make	Mercedes-Benz	Allison	Rolls-Royce	Hispano-Suiza	Junc
2. Model	DA-601A	V-1710C-15	Merlin X	12Y-51	211
3. Number of cylinders	12	12	12	12	12
4. Arrangement	Inverted Vee	Vee	Vee	Vee	Inverted Vee
5. Bore (inches)	5.7	5.5	5.4	5.9	5.9
6. Stroke (inches)	Stroke	6.0	6.0	6.7	6.5
7. Piston displacement (cubic inches)	2,070	1,710	1,647	2,197	2,136
8. Military rating (horsepower) ...	1,000	1,090	1,025	1,100	975
9. Military rating (r.p.m.) ...	2,400	3,000	3,000	2,400	2,300
10. Military rating altitude (feet) ...	14,760	13,200	17,750	10,696	15,584
11. Hypothetical horsepower at 15,000 feet	990	1,020	(High Blower) 1,150	920	(High Blower) 990
12. Take-off rating (horsepower) ...	1,150	1,040	1,045	1,100	1,100
13. Take-off rating (r.p.m.) ...	2,500	3,000	2,850	2,400	2,400
14. B.M.E.P. (military rating) ...	158	168	164	156	157
15. B.M.E.P. (take-off)	167	160	176	166	170
16. Compression ratio	6.8	6.65	—	7.0	6.5
17. Take-off piston speed (feet per minute)	2,625	3,000	2,850	2,690	2 600
18. Total piston head area (sq. inches)	306	285.5	275	328	328
19. Take-off horsepower per sq. in. piston area	3.84	3.65	3.81	3.36	3.36
20. Take-off horsepower per cubic inch displacement per minute	.000111	.000101	.000111	.000104	.000107
21. Dry weight (pounds)	1,367	1,325	1,394	1,085	1,356
22. Unit weight (pounds per take-off horsepower)	1.19	1.27	1.33	.993	1.23
23. Height (inches)	40.5	42.1	41.1	37.2	41.7
24. Width (inches)	29.1	30.6	29.8	30.1	31.7
25. Overall length (inches) ...	84.0	94.5	75.1	84.1	68.7

Increasing the Altitude Performance of Aircraft Engines. (V. A. Dollerzhal, Aeronautical Engineering, U.S.S.R., Vol. 15, No. 3, March, 1941, pp. 39-42.) (93/25 U.S.S.R.)

The conclusions arrived at are as follows:—

To increase the m.e.p. of the engine at altitude, the most suitable combination is a moderate compression ratio, and a high degree of supercharge.

It is doubtful whether the necessary supercharge is obtainable from a single stage blower. Either a two-stage blower, or a combination of mechanically operated blower and exhaust driven turbo-blower are probably required.

In connection with high altitude operation, the question of the blower speed becomes important. The present standardised two-speed drive becomes inefficient at intermediate altitudes, and the need for some infinitely variable gear is indicated.

For this purpose the author described a hydraulic coupling, somewhat on the line of that fitted to the German DB. 601 engine.

Cam Shape for the Valve Operation of Four-Stroke Engines. (H. Denkmeier, Luftwissen, Vol. 8, No. 5, May, 1941, pp. 157-162, and No. 6, June, 1941, pp. 181-188.) (93/26 Germany.)

A series of harmonic cams producing the same valve lift with different acceleration characteristics were investigated both theoretically and experimentally, special attention being paid to the effect of valve tappet clearance. It appears that the electricity of the valve operating gear, including lay shaft drive (if present), is of paramount importance in determining the force between cam and tappet. The " give " in the operating gear will generally increase with increasing radius of curvature of the cam flank and this will reduce the impact force automatically. The opening of the valve can then be carried out rapidly without undue risk. In the case of excessive tappet clearance, however, the symmetrical cam of high acceleration may overload the valve stem during the closing operation. Although according to the author, very rapid opening of the valve does not lead to mechanical difficulties, engine tests show that such rapid opening does not necessarily lead to an increase in power. Possible limitations due to gas speed and spring flutter are not considered by the author.

Bramo Jafnir Petrol Injection Radial Aero Engine, Type 323 A-D and 323 P. (Luftwissen, Vol. 8, No. 6, June, 1941, pp. 189-193.) (93/27 Germany.)

These nine-cylinder radials (bore 154 mm., stroke 160 mm.) are a development of the SH. 22 radial, manufactured by Siemens and Halske.

Earlier models of the 323 were fitted with Sum carburettors. The replacement of these by petrol injection pumps does not appear to have affected the power output appreciably. The most economic fuel consumption has, however, been reduced by about 10 per cent. Types C and D are both fitted with a low speed supercharger (9.5 gear ratio) and only differ in the value of the airscrew reduction gear (1.41 and 1.61 respectively). These models develop 1,000 h.p. at take-off. Types A and B are both supercharged to 4,200 m. (11.4 blower ratio) and differ again in airscrew reduction gear. These engines develop 730 h.p. at the rated altitude. Type P (not previously built) differs from the others in having a two-speed epicyclic blower gear (9.6 and 12.4 ratio), which enables the engine to combine 1,000 h.p. at take-off with an output of 775 h.p. at 4,250 m. Details of the blower reduction gear are given. Of special interest is a vapour trap which is incorporated in the fuel line between the supply pump and the injection pump.

Performance Tests on an Internal Combustion Gas Turbine. (A. Stodola, Z.V.D.I., Vol. 84, No. 1, 6/1/40, pp. 17-20.) (93/28 Germany.)

The plant designed by B.B.C. (Switzerland) is intended for emergency operation at the Neuchâtel electric power station and was exhibited at the Swiss Engineering Exhibition, 1938. It is now housed in a bomb-proof underground section of the power station. In order to save cost and space, the turbine exhausts straight into the atmosphere, and no heat exchangers are installed. The multi-stage axial compressor running at 3,000 r.p.m., delivers about 220,000 kg. of air/hour, at a maximum compression pressure of 4.34 atm. abs. ($t = 203$°C.). Only a portion of this air is directly burnt by passing the oil burner and the combustion gases mixing with the excess air enter the turbine (multi-stage axial) at 550°C. max. At maximum load the shaft horse-power of the turbine is 15,660 kW., and that of the compressor 11,480 kW., leaving an available power output of 4,180 kW. The corresponding thermal efficiency is 18 per cent. (compression efficiency of blower 85 per cent., and turbine efficiency 88 per cent.).

It is specially emphasised that this novel power plant, since it requires no cooling water, is extremely compact. By fitting heat exchangers an appreciable increase in the thermal efficiency should become possible.

Surface Quality of a Medium Carbon Steel. (O. W. Boston and W. W. Gilbert, Engineering, Vol. 152, No. 3,939, 11/7/41, p. 35.) (93/29 Great Britain.)

For the S.A.E. 3,140 steel in a normalised and annealed condition, when cut dry, the surface quality produced at low cutting speeds, as observed from photographs and profilograms, is poor. As high speeds are reached the surface quality is greatly improved. At a certain minimum speed, called the optimum speed, the cutting edge of the tool actually produces the machined surface which is superior to the surface at all lower speeds in which the chip is removed by means of a built-up edge. Photographs and profilograms show little difference in surface quality at high cutting speeds when various types of cutting fluids are used. At low speeds, however, it appears that the surface quality is improved as compared with dry cutting when a cutting fluid, consisting of a sulphurised mineral or sulphurised base oil, is used. The optimum cutting speed for each of several structures is lowest for the hardest steel and highest for the softest steel. It appears also that the surface quality changes but slightly as the speed, cutting fluid, or structure is changed for values of cutting speed above the optimum.

The Spot Welding of Light Alloys. (Tylecote, Trans. Inst. Weld., April, 1941, pp. 56-75.) (Met. Vick. Tech. News Bull. No. 770, 11/7/41, p. 8.) (93/30 Great Britain.)

Literature, published up to October, 1940, on the spot welding of light alloys is reviewed. The subject matter includes weldability, machines and machine settings, surface preparation, electrodes, strength properties, etc. A bibliography and an author index are appended.

(Abstract supplied by Research Dept., Met. Vickers.)

The Welding of Non-Ferrous Metals. (West, Trans. Inst. Weld., April, 1941, pp. 76-112.) (93/31 Great Britain.)

The author reviews literature published during 1939-1940 on non-ferrous metal welding. It is stated that the main object has been to present as complete a picture as possible of the present position of non-ferrous metal welding and its problems. The subject matter is presented in the form of short abstracts and a subject and name index are appended.

(Abstract supplied by Research Dept., Met. Vickers.)

Ball and Roller Bearings. (G. A. Ungar, Machinist, 5 and 12/7/41, pp. 130 E and 138 E-140 E.) (93/32 Great Britain.)

These issues contain an article dealing with the basic factors underlying the selection of ball and roller bearings, since confusion may arise from the wide differences in load capacity ratings for bearings of the same type and size, but of different makes. The author outlines how catalogued ratings may be corrected to a standard of comparison, factors discussed including the ratio of expected to tested life, actual bearing life, loading per unit of area, etc. Criteria of comparison are tabulated for various types of ball and roller bearings and for some needle bearings.

(Abstract supplied by Research Dept., Met. Vickers.)

Ultrasonics—A New Metallurgical Tool. (Cosman, Iron Age, 15/5/41, pp. 48-50.) (93/33 Great Britain.)

The technique of ultrasonics is stated to be little beyond the theoretical stage, but some of its possibilities as an engineering tool are indicated. Ultrasonic radiations, produced by magneto-striction or the piezo-electric machine, occupy a position in the frequency scale between the upper limit of human hearing and radio waves. Fine cracks or impurities in material obstruct the passage

of these waves, absorption and reflection taking place. They are also stated to produce marked physical effects and may be used for fatigue testing degassing liquid metals, speeding up hardening operations and other purposes.

(Abstract supplied by Research Dept., Met. Vickers.)

Control of Carbon Content of Protective Gas in Heat Treatment Furnaces. (Scientific American, Vol. 165, No. 2, Aug., 1941, p. 63.) (93/34 U.S.A.)

In the Endogas method of treating steel, developed by Westinghouse Electric and Manufacturing Company, a protective gas is used in the heat-treating furnaces to prevent softening or scaling of the surface during treatment. It is necessary, however, that the protective gas be of precisely the correct composition for the work in hand.

Since the carbon content or pressure of Endogas is the critical factor, it must be carefully controlled. It is not possible, however, to make this determination quickly enough by ordinary chemical analysis; and a special so-called " hot wire carbon gauge " has been produced for this purpose. In this gauge a thin steel wire is heated for a few minutes in a test sample of the Endogas until a " carbon balance " is established between the gas and the wire. Because the wire retains its carbon in a solid form known as martensite, its electrical resistance and certain other physical properties can then be used as a measure of its carbon content, which in turn measures the carbon pressure of the gas. By means of this gauge the quality of the furnace atmosphere can be quickly determined at any time and pre-adjusted to suit the carbon content of any steel to be treated.

Synthetic or Natural Rubber. (Inter. Avia., No. 766, 27/5/41, p. 1-4.) (93/35 Switzerland.)

Five different types of synthetic rubber are listed:—

1. *Neoprene* (polymers of chloroprene).
2. *Thiokole* (reaction products of aliphatic dihalides with alkali polysulfides).
3. *Perbunan, Buna S, Ameripols, Hycars, Chemigum* (co-polymers of butadiene with other polymerisable compounds).
4. *Koroseal* (plasticised polymers of vinyl chloride).
5. *Vistanex* (polymers of isobutylene).

All of these differ chemically from natural rubber.

The purely mechanical properties of composition of natural rubber are not surpassed to any marked extent by those of synthetic rubber stocks, so that in view of the present high production cost of synthetic rubber it is improbable that synthetic rubber will replace the natural product in articles which depend for utility on such properties alone. It frequently happens, however, that in service rubber must be subjected to influences which rapidly impair its mechanical excellence. Often high temperatures, direct exposure to bright sunlight, or contact with oil cannot be avoided. In such cases compositions of synthetics or of mixtures of synthetics with natural rubber may result in certain improvements.

The Synthetic products are superior to natural rubber in the following points:—

(*a*) Resistance to swelling and deterioration in contact with oils, organic solvents and water.
(*b*) Resistance to cracking in sunlight.
(*c*) Resistance to deterioration by heat.
(*d*) Resistance to powerful oxidising agents.
(*e*) Resistance to diffusion of gases.
(*f*) Possibility of compounding to graphite so as to render the product electrically conductory.

Natural rubber still exhibits superiority to all the synthetics now available in :—

(*a*) Elasticity and rebound.
(*b*) Low heat generation through hysteresis.
(*c*) Extensibility.
(*d*) Resistance to stiffening at low temperatures.

The synthetic rubber industry in Germany started on its way in 1934 with an annual output of 10 tons, was claimed to have reached 4,000 tons already by 1937, and is now estimated to produce at the rate of about 60,000 tons annually. As a comparison, the American industry now produces only about 3,000 tons of synthetic rubber a year, the yearly consumption of natural rubber being of the order of 750,000 tons.

Determination of the Shearing Stresses in Axially Symmetrical Shafts Under Torsion by Finite Difference Methods. (S. T. Newing, J. Phil. Mag., Vol. 32, No. 210, July, 1941, pp. 33-49.) (93/36 Great Britain.)

The application of finite difference methods to the determination of numerical solutions of differential equations provides a standard method of attack upon problems which are not amendable to exact formal analysis. Some methods of this kind are discussed in detail in a paper by L. F. Richardson,* who applied them to the determination of the stresses arising in masonry dams. It is found, however, that when numerical solutions are required over semi-infinite plane regions, the method described in this paper for arranging that the convergence of the process of iteration shall be rapid is not applicable.

The present paper describes the application of a similar finite difference method to three problems relating to the torsion of symmetrical shafts of different types, and treats the convergence of the process from a standpoint entirely different from Richardson's. The resultant shear stresses are determined for hollow shafts of varying section and also for a shaft with a concentric bore whose radius is 0.25 that of the shaft.

Friction and Adhesion. (J. J. Bikerman, J. Phil. Mag., Vol. 32, No. 210, July, 1941, pp. 67-76.) (93/37 Great Britain.)

Recent literature on sliding friction is critically reviewed, it is concluded that :—

1. Friction cannot be due to welding as the law of friction and its numerical constant may be identical for the pairs Pt/Pt, Pt/wood, and wood/wood.
2. Friction cannot be due to adhesion in general as no adhesion can be detected by measuring the normal force.
3. Coulomb's law cannot be reconciled with the adhesion hypothesis by assuming the real area of contact to be proportional to the load; this assumption is refuted by experiments using decreasing loads.
4. In experiments which seemed to prove that friction was not due to the surface roughness, the real friction was not measured; mostly it was scratch hardness.
5. " Stick-and-slip " patterns have no bearing on the mechanism of friction.
6. The absolute values of the coefficient of friction are accounted for by Coulomb's theory attributing friction to surface asperities.

The Buckling of Heavy Struts. (F. A. Willers, Z.A.M.M., Vol. 21, No. 1, Feb., 1941, pp. 43-51.) (93/38 Germany.)

The buckling of short struts is not affected by the weight of the strut. In the case of drills for deep bore holes, the weight of the rod is considerable and will affect the buckling load. Starting with the well known principle of minimum energy, stability equations and boundary conditions are developed by the author

* Phil. Trans. Roy. Soc. A., ccx, pp. 307-57 (1910).

for this case. The integration of the differential equations is carried out by means of Bessel and Lommel functions. The asymptotic representation of these functions enables the buckling force of very large rods to be estimated.

The Strength of Lugs (Eye Bolts). (O. Volkersen and R. Goschler, Luftwissen, Vol. 8, No. 5, May, 1941, pp. 151-156.) (93/39 Germany.)

If

ρ = tensile load,
s = thickness of plate,
d = diameter of bolt hole,
$2a_1$ = width of plate,
a_1 = distance of hole from side of lug,

the maximum resultant stress in the lug on either side of the hole is given by

$$\sigma_L = 2.4 \frac{\rho}{(2a_1 - d)\, s} \text{ (app.)}$$

provided the elastic range of the materials is not exceeded. The ultimate breaking load of the lug cannot, however, be estimated from this equation, since the stress distribution will be considerably modified by the yielding of the material.

Experiments have shown that the breaking load does not only depend on "a_1" (defined above), but also on "a" (distance of hole from end or vortex of lug) and on the ratio s/d. The plan form of the lug on the other hand (rectangular, round or necked) plays only an unimportant rôle.

The authors have carried out a series of experiments both on the ultimate strength of lugs (fractures either at vortex, *i.e.*, above hole or at sides of hole) as well as on the limiting tensile loads for either 0.1 and 1 per cent. permanent extension of the eye hole.

The results are given in a series of tables and graphs and cover dural plates ranging from 0.6 to 10 mm. in thickness. For most of the experiments, the diameter of the hole was 10 mm.

In order to utilise the material to the utmost, a lug should be designed so as to be equally strong at vortex and sides of hole (*i.e.*, resistance to crushing at hole equal to tensile strength of lug section perpendicular to load under these conditions). For a given value of a_1/d, a/a_1 will increase rapidly as s/d diminishes.

This is shown in the following table:—

s/d	a/a_1	a_1/d
0.08	1.8	1.0
0.10	1.2	1.0
0.15	2.3	1.5
0.20	1.5	1.5
0.60	1.4	1.5

Fatigue Testing Machines for Large Specimen. (E. Erlinger, Luftwissen, Vol. 8, No. 6, June, 1941, pp. 177-181.) (93/40 Germany.)

Experience has shown that mechanical strength investigations should be carried out whenever possible on the actual structural element, or if that is not feasible, the specimen undergoing test should closely resemble the finished product as to dimensions, shape and surface finish. Whilst tensile test machines capable of handling large samples have been in use for some time, the range of fatigue testing machines available so far only enabled relatively small samples to be tested. In this article the author gives some details of large fatigue testing machines designed by him to cover the range of bending, torsion and compression-extension.

(1) *Bending Fatigue.*—Rotating specimen, max. bending moment 750 mkg., max. length of sample 65 cm. The bending moment applied may be either constant or variable. A small axial load ensures separation of sample as soon as broken and prevents further damage to the surfaces of the fracture.

(2) *Torsion Fatigue.*—Three machines (" torsators ") working on the resonance principle are described with maximum torques of ±300, 1,000 and 2,000 mkg. respectively. If required, a static torque can be superposed on the fluctuations. The forcing frequency (20 or 50 cycles/sec.) is obtained by a rotary out-of-balance mass attached excentrically to one of the inertia masses of the system. These masses can be tuned so as to obtain resonance and the vibration amplitude of the specimen is maintained constant throughout the test by an automatic control of the forcing frequency. In this manner the development of a crack can be detected before complete fracture of the specimen. The machines are not only big enough to handle complete engine crankshafts, but provision is also made to control the temperature of the specimen during the tests and subject it to the influence of corrosive agents.

(3) *Tension-Compression* (*Pulsator*).—An oscillating stress up to ±25 tons at a frequency of 40 cycles per second can be applied to the specimen through the agency of a heavy leaf spring subjected to forcing impulses. A static stress up to 25 tons can be superposed, the maximum load thus being equal to 50 tons. A photograph shows an aero engine piston undergoing tests on a machine of this type.

Both " torsators " and " pulsators " are mounted on rubber blocks so as to isolate ground vibrations.

Acoustic Models of Radio Antennas. (E. C. Jordan and W. L. Everitt, Procs. of I.R.E., Vol. 29, No. 4, April, 1941, pp. 186-194.) (93/41 U.S.A.)

The large number of independent variables in antenna arrays make it advisable to develop means for rapidly surveying the field patterns which may be obtained. The advantages in the use of acoustic models for this purpose are shown.

Two analogous acoustic antennas are developed, one for the measurement of fields at a distance and the other for fields close to the antenna. The procedure which can be followed in setting up the models and making measurements is outlined.

Advantages are demonstrated for the acoustic model in the study of non-sinusoidal current distributions, and their effect on the field pattern.

The measurement of mutual impedance between antennas may be conveniently carried out with one of the models. The arrangement for phasing and magnitude control in a multi-unit array are shown. The field of an acoustic model is shown in comparison with the field of an actual array which it simulates.

Control of Night Error in Aeroplane Direction Finding (*Digest*). (H. Busignies, Procs. of I.R.E., Vol. 29, No. 4, April, 1941, p. 222.) (93/42 U.S.A.)

This paper describes the development of a method enabling pilots to determine the accuracy of night bearings obtained by means of a radio compass in the wave length range of 200 to 2,000 metres (150 to 1,500 kilocycles), and the effect on the indication when the plane passes through the combination of fields due to the reflection of waves from the *E* layer or from a mountain side. Consideration is given to the appearance of the night error on the ground and in altitude, taking into account the simultaneous presence of (1) the direct wave; (2) the sky wave; and (3) the sky wave reflected from the ground. It is demonstrated that the night error is smaller in the air than on the ground; also that there are regions in the atmosphere where the night error is very small.

The dynamic aspect of the night error is then studied in the case of a plane moving through the above-mentioned system of waves. How the radio-compass indication changes regularly about a mean value, whether correct or not,

according to the polarisation of the sky wave, is next discussed. All cases of polarisation are examined.

In conclusion, a number of rules are formulated relative to night direction finding on board aeroplanes above land or sea, supplemented by maps showing areas where direction finding is safe, unsafe, or dangerous. The maps show that the practical range of night direction finding is increased substantially by the correct interpretation of the radio-compass indications.

A Mechanical Calculator for Directional Antenna Patterns (Digest). (W. G. Hutton, Procs. of I.R.E., Vol. 29, No. 4, April, 1941, p. 224.) (93/43 U.S.A.)

The object of this paper is to describe a mechanical directional-antenna-pattern calculator to be used when all the factors are known that completely determine the pattern. This mechanical directional-antenna-pattern calculator is a machine which can be adjusted for any or all the factors that determine completely the directional pattern, and which on operation will automatically rotate the vectors that represent the relative antenna fields in such a way with respect to each other that the resultant vector or field ratios may be read directly.

The design problem for a directional-antenna pattern may involve the calculation of several trial patterns before the correct pattern is obtained. Thus, a machine such as this paper describes will speed up and simplify design work for directional arrays.

The standard equation for field-intensity patterns is shown and an analysis is made to show that the result given by the machine is the solution to this equation.

The operating procedure is given for calculating the horizontal pattern with the machine described. The operating procedure is given for calculating the vertical-field pattern for any particular horizontal angle after the horizontal pattern has been figured by use of the machine.

The procedure is given for converting the vector values given by the machine to micro-volts per metre both for the horizontal and vertical patterns.

Aerial Photography in Winter. Experience of the Operation of the A.F.A. Aerial Camera Under Winter Conditions. (P. G. Timofeev, Air Fleet News, U.S.S.R., Vol. 23, No. 2, Feb., 1941, pp. 254-258.) (93/44 U.S.S.R.)

A list of defects in design and breakdowns in operation of various (Russian) service types of aerial cameras is given. The main troubles due to winter conditions are:—Freezing of the film-feed rollers, freezing of the shutter, rupture of flexible shafts.

The heating device of the camera should be carefully inspected before the flight. The heater should be adjusted to a number of temperature stages, since in view of the danger of the shutter freezing-up at temperatures not requiring general heating of the camera, it is desirable to have an auxiliary heating stage for the shutter only.

A Device for Joining Short Lengths of Aerial Photo Films. (K. N. Sakharov, Air Fleet News, U.S.S.R., Vol. 23, No. 3, March, 1941, pp. 263-264. Translated by L. J. Goodlet.) (93/45 U.S.S.R.)

In the practical evaluation of aerial reconnaissance material, it is frequently necessary to deal with short length aero films, usually those from the "AFA-I" aerial camera.

The length of such films does not exceed nine metres, and they are developed in apparatus designed for handling films of 28-30 metres in length, taking from 30 to 35 minutes for the operation. Consequently, if the laboratory receives three to six such films, it will require $1\frac{1}{2}$ to 3 hours to deal with them. Furthermore, the utilisation of the apparatus will be one-third only of the designed capacity, and the consumption of solutions and chemicals will be correspondingly excessive.

The most economical method of treating such short films is, therefore, to handle a number of them simultaneously by glueing them together into one strip.

The glueing is performed in the following manner:—Using a brush or a tuft of cotton wool, ordinary technical " Emaillit " is applied to the emulsion side of the aero film (about 4-5 cm. wide). Before the adhesive dries, the section to be joined on is applied with the gelatine side to the glued section and rubbed down with a clean rag until the adhesive has dried. This method is reliable, the glued film does not tear when passed through the standard Air Force developing appliance, nor dissolves in the liquid used in the treatment of negatives: De-sensitiser, water, developer, fixing bath, or alcohol.

Determination of Position and Altitude of an Aircraft in Space by Means of Photogrammetric Methods. (M. di Jordis, Atti di Guidonia, No. 43, 10/2/41, pp. 21-36.) (93/46 Italy.)

In the usual method of aerial survey, the ground is photographed from an aircraft flying at a known altitude and the resulting picture converted into a scalar map by means of special machines, provided the inclination of the optre axis of the camera with the vertical is known. It is obvious that the procedure can be reversed, *i.e.* if the relative position of a number of landmarks appearing on the photograph is already known from a terrestrial map, the position of the camera at the instant the photograph was taken can be determined. The author describes a simplified form of projector which will achieve this and estimates that the error in altitude is not more than .1 per cent. for the range 2,000 to 5,000 m. whilst angular inclination of the aircraft can be read to about ½°, provided the exposures are not taken too near the vertical. By taking a series of ground photographs each with a clock face image giving time to 1/50 sec., the speed of aircraft between successive exposures can be calculated.

Cases of Petrol Poisoning in Flight. (P. F. Vokhmyani, Air Fleet News, U.S.S.R., Vol. 23, No. 3, March, 1941, pp. 265-266.) (93/47 U.S.S.R.)

Two recent instances of poisoning by petrol fumes in flight are described. Both refer to " R2 " two-sector bombers with open cockpit. In one case the pipe line between fuel tank and engine fractured; in the second, the nipple on the fuel pressure gauge became unscrewed. In neither case did the defect reveal itself, as a petrol spray or splash and the smell in the cockpit was not unduly marked. Nevertheless, the broken pipe led to both pilot and observer ultimately losing consciousness and being injured in the subsequent crash. The consequences of the unscrewed nipple were not so serious since the pilot landed soon after the smell became noticeable. The landing was, however, rough and the handling of the aircraft much below the standard for this pilot. The latter, however, seems to have been unaware of this.

It must consequently be assumed that in both cases petrol poisoning in flight took place, owing to leakage and an accumulation of highly concentrated fuel fumes in the cockpit. The handbook description of petrol-fume poisonng states: " Light cases of petrol or paraffin poisoning are manifested in the form of a slight intoxication. The symptoms are hallucinations of short duration."

In serious cases, reduced pulse with irregular breathing, contracted or dilated pupils, foam on the lips, cutaneous hæmorrhage, and loss of consciousness result. Loewe and Kolesnikov (Baku) and Lazarev (Leningrad) found by experiments on animals that aviation spirit (pure) is a heart toxic. Insensibility results from a concentration of 0.05 gm. per cubic metre after 4-5 hours.

Since doped petrol was used in the above cases, the question arises whether poisoning was due to the petrol or the added tetra-ethyl lead. Acute tetra-ethyl lead poisoning is distinguished by the following symptoms: insomnia, extreme excitation, visual and aural hallucination, delirium, talkativeness, insecure gait. In light cases, insomnia, nightmare, sickness, bad taste in the mouth, giddiness,

headache, general lassitude. Characteristic for tetra-ethyl lead poisoning is a dormant form lasting several days. The official handbook states that owing to the small percentage of addition, poisoning with doped petrol is scarcely distinguishable from the effects of pure petrol.

Comparing these descriptions of symptoms with the two cases quoted above, it may be concluded that, even if the dope participated in the effect, the principal poisoning was by means of petrol. Neither did tetra-ethyl lead poisoning appear later.

CONCLUSIONS.

1. Acute poisoning by the fuel, in case of leakage in flight, is possible even in an open cockpit.
2. In both cases mentioned, the poisoning manifested itself as rapid, but not deep, insensibility, after a short previous phase of excitation.

The Reflections of Sound Pulses by Convex Parabolic Reflectors. (F. G. Friedlander, Proc. Cambs. Phil. Soc., Vol. 37, Part 2, April, 1941, pp. 134-149.) (93/48 Great Britain.)

The reflexion of a train of simple harmonic waves by a convex parabolic of revolution, and by a parabolic cylinder, has been discussed by Lamb.* In the present paper these results are extended to the reflexion of plane waves of arbitrary form. It is found that on the introduction of suitable variables the equation of sound propogation transforms (in each case) into a simpler equation whose general integral can be obtained by quadratures. Two unknown functions are introduced during the integration, which have to be determined from the boundary conditions. This involves in both cases the solution of a Volterra integral equation, which is effected numerically by calculation of the first terms in the series development of the resolving kernel. An interesting feature of the solutions obtained is that when a suitable time scale is introduced (for a sharp-fronted pulse the time must be counted from the onset of the wave), the reflected wave experienced is the same at all points on any paraboloid (or parabolic cylinder) confocal with the reflector.

Experiments in Approximating to Solutions of a Partial Differential Equation. (W. G. Bickley, J. Phil. Mag., Vol. 32, No. 210, July, 1941, pp. 50-66.) (93/49 Great Britain.)

The author describes a number of experimental attempts to approximate to the solution of the differential equation

$$\frac{\partial^2\theta}{\partial\xi^2} = \frac{\partial\theta}{\partial z}$$

for the ranges $0 < \xi < 1$, $0 < z < \infty$ with certain boundary and initial conditions. By assuming a polynomial in ξ, the coefficients of which are functions of z, the problem is reduced to solving ordinary differential equations for these coefficients. These differential equations may be constructed by collocation, or by the Galerkin method of (weighted) integrals. The initial conditions are similarly treated. Quite good agreement is obtained with only two disposable coefficients; if interest is largely centred in one point, collocation at that point produces results better than the Galerkin method. The method of least squares applied to the error is apparently not well suited for use with an infinite range, unless it is the asymptotic behaviour only which is sought.

* Lamb. "On Sommerfield's diffraction problem; and on reflexion by a parabolic mirror." Proc. London Math. Soc. (2), 4 (1906), 190.

Expansion Turbine Producing Low Temperature Applied to Air Liquefaction. (P. Kapitza, Journal of Physics, U.S.S.R., Vol. 1, No. 1, 1939, pp. 7-27.) (93/50 U.S.S.R.)

In the well known Linde process, the air is compressed to about 200 atmospheres and expanded through a nozzle, the resulting cooling being due to the Joule-Thomson effect. This effect is small in the case of air and much greater cooling would result if the expanding gas could be made to do useful work.

The author has succeeded in designing a suitable radial turbine for this expansion, the required pressure drop being only of the order of five atmospheres instead of the 200 atm. of the Linde machine. The main difficulty in the design of such expansion turbines is the rotor friction and proper utilisation of the large centrifugal forces in the medium due to its relatively high density. The final design has a rotor of only 8 cm. diameter, weighing 250 gm. and running at 40,000 r.p.m. Although this speed is well above the critical speed of the shaft, stability of operation required the introduction of a damper. The rotor is not mounted directly on the shaft, but a special universal joint allows the principal axis of inertia to coincide automatically with the axis of rotation. The expansion efficiency is of the order of 83 per cent. and the plant will yield about 30 kg. of liquid air per hour, at an energy cost of about 1.7 kw.h. per kg. Although this energy consumption is about 30 per cent. greater than that of orthodox installations, the simplicity, reliability and safety of the turbine plant are great assets. The space required is about one-sixth that of an equivalent Linde machine and the starting period only of the order of twenty minutes.

LIST OF SELECTED TRANSLATIONS.

No. 36.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft Production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

TRANSLATION NUMBER AND AUTHOR.	TITLE AND REFERENCE.
AERO- AND HYDRODYNAMICS.	
1220 Multhropp	*Aerodynamics of the Fuselage.* (L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 52-66.)
1226 Eckert, B ... ... Pfluger, F.	*Resistance Coefficients of Commercial Type of Wire Grids.* (L.F.F., Vol. 18, No. 4, 22/4/41, pp. 142-146.)
1234 Kuhle, E.	*Numerical Calculation of the Neutral Point of a Wing.* (L.F.F., Vol. 17, No. 9, 20/9/40, pp. 257-266.)
AIRCRAFT AND ACCESSORIES.	
1219 Wollf, H.	*The Influence of the Mach Number on the Efficiency of Airscrews.* (L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 67-69.)
1227 Brode, K	*Dornier Do. 18 Flying Boat Fitted with B.M.W. 132 Air-cooled Radial Engine.* (Luftwissen, Vol. 7, No. 12, Dec., 1940, pp. 420-422.)
1228 Hiorth, N.	*Towed Gliders.* (Flugsport, Vol. 33, No. 1-2, pp. 10-15 and 35-37.)
STRUCTURE.	
1218 Fohlbusch, H. ... Wagner, W. ...	*The Loading of Circular Frame Members in Shell Structures.* (L.F.F., Vol. 18, No. 4, 22/4/41, pp. 122-127.)
1224 Wagner, H. ... Simon, H.	*The Provision for Taking up Longitudinal Forces in Thin Walled Cylindrical Shell Structures.* (L.F.F., Vol. 13, No. 9, 1936, pp. 293-308.)
THEORY AND WARFARE.	
1223 Borsani, D. ...	*Vulnerability of Aerial Targets.* (L'Ingegnere, Vol. 18, No. 5, 1940, pp. 369-374.)
1225 Stehli, R. H. ...	*Estimation of Aircraft Distance with the Help of Binoculars.* (Flugwehr und Technik, Vol. 2, No. 10, Oct., 1940, pp. 226-227.)
1232 Kuhlen Kamp, A. ...	*Sound Location of Invisible Aircraft.* (Z.V.D.I., Vol. 85, No. 17, 26/4/41, pp. 393-400.)
MISCELLANEOUS.	
1233 Ackeret, J. ... ... Keller, C.	*Closed Circuit Aerodynamical Heat Engines (Hot Air Turbines).* (Z.V.D.I., Vol. 85, No. 22, 31/5/41, pp. 491-500.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING JULY, 1941, TOGETHER WITH LIST OF NEW TRANSLATIONS RENDERED AVAILABLE.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of the Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example that published by the Aeronautical Research Committee) is already known to these Staffs.

THEORY AND PRACTICE OF WARFARE.

78/1	Great Britain	*Bristol Beaufort General Purpose Aircraft.* (Engineering, Vol. 151, No. 3,934, 6/6/41, pp. 456-457.)
78/2	Great Britain	*Civilian Population Under Bombardment.* (R. J. Bartlett, Nature, Vol. 147, No. 3,736, 7/6/41, pp. 700-701.)
78/3	Great Britain	*Anti-Scatter Treatment for Windows.* (H. M. Llewellyn, J. of Soc. of Chem. and Ind., Vol. 60, No. 23, 7/6/41, pp. 433-434.)
78/4	Great Britain	*An Automatic Aid to the Rapid Testing of War Gases in the Field.* (Huson and Hardwick, J. of Soc. of Chem and Ind., Vol. 60, No. 23, 7/6/41, pp. 436-437.)
78/6	Germany ...	*German Air Raid Defence of Factories.* (C. Wachtl, Chem. and Metallurgical Eng., Vol. 78, No. 4, April, 1941, pp. 92-94.)
78/7	Germany ...	*Mass Production of He. III.* (Motor Schau., Vol. 5, No. 1, Jan., 1941, pp. 48-52.)
78/8	Germany ...	*F.W. "Kurrier" (Photograph).* (Motor Schau., Vol. 5, No. 2, Feb., 1941, p. 127.)
78/9	Germany ...	*Photograph of Modern German Seaplanes.* (V. Kinzel, Motor Schau., Vol. 5, No. 3, March, 1941, pp. 200-253.)
78/10	Switzerland...	*Bombing by Day.* (E. Amstutz, Inter. Avia., No. 763, 9/5/41, pp. 1-3.)
78/11	U.S.A./ Great Britain	*Atlantic Ferry (U.S.A.-Great Britain).* (Inter. Avia., No. 763, 9/5/41, pp. 6-7.) (Abstract available.)
78/12	Spain ...	*Hispano H.S. 42 Trainer.* (Inter. Avia., No. 763, 9/5/41, pp. 8-9.)
78/13	Germany ...	*Focke-Wulf F.W. 158 Single-Seat Pusher Fighter.* (Inter. Avia., No. 763, 9/5/41, p. 10.)
78/14	U.S.A. ...	*Beechcraft AT. 7 Trainer.* (Inter. Avia., No. 763, 9/5/41, p. 11.)
78/15	U.S.A. ...	*Boeing B. 17 D. Flying Fortress (Photograph).* (Inter. Avia., No. 763, 9/5/41, p. 1.)
78/16	Switzerland...	*Estimation of Aircraft Distance with Binoculars.* (R. H. Stehli, Flugwehr und Technik, Vol. 2, No. 10, Oct., 1940, pp. 226-227.)
78/17	Germany ...	*German A.A. Gun of 130 mm. Calibre.* (Flugwehr und Technik, Vol. 2, No. 10, Oct., 1940, pp. 227-228.)

78/18	Germany ...	*German Air Raid Defence of Factories.* (C. Wachtel, Chemical and Metallurgical Engineering, Vol. 48, No. 4, April, 1941, pp. 92-94.) (Abstract available.)
78/19	Germany ...	*Focke-Wulf F.W. 189 Short Reconnaissance Plane.* (Inter. Avia., No. 760, 16/4/41, pp. 6-7.)
78/20	U.S.A. ...	*Timn P.T.-160-K Plastic Trainer.* (Inter. Avia., No. 760, 16/4/41, p. 9.)
78/21	Switzerland...	*Piaggio P. 23 R. Three-Engined Bomber (Photograph).* (Inter. Avia., No. 760, 16/4/41, p. 1.)
78/22	U.S.A. ...	*Organisation of U.S. Air Force.* (Inter. Avia., No. 762, 1/5/41, pp. 1-5.)
78/23	U.S.A./ Great Britain	*Caribou (Extra Weight of British Version of Bell P. 39).* (Inter. Avia., No. 762, 1/5/41, p. 8.)
78/24	U.S.A./ Canada ...	*Fairchild M. 62 Trainer.* (Inter. Avia., No. 762, 1/5/41, p. 8.)
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78/645 U.S.A. ... *Summary of Proceedings of Ninth Annual Meeting of Inst. Aero. Sciences* (30/1/41). (A. Klemin, J. Aeron. Sci. (Review Sect.), Vol. 8, No. 5, March, 1941, pp. 45/59.)

78/649 Great Britain *The Purification of Air and Gases.* (Metal Industry, Vol. 158, No. 24, 13/6/41, pp. 507-509.)

78/651 Great Britain *Adjustable Blade Turbines.* (Terry, Power, May, 1941, pp. 76-78.) (Abstract available.)

78/653 U.S.A. ... *Administrative Report for Fiscal Year ending June 30th,* 1940. (26th Annual Report, N.A.C.A.) (Abstract available.)

78/654 Great Britain *A New Process for Liquifying Air* (*Expanding Gas doing Work in a Turbine*). (J. H. Awbery, Nature, Vol. 18, No. 3,740, 5/7/41, p. 14.)

78/655 U.S.S.R. ... *Spraying Beetroot Crops from the Air.* (L. D. Lavrov and E. V. Sazonov, Civil Aviation, U.S.S.R., Vol. 2, No. 4, April, 1941, pp. 19-21.)

78/656 U.S.S.R. ... *New Self-Priming Pumps.* (A. E. Musienko, Civil Aviation, U.S.S.R., Vol. 2, No. 5, May, 1941, pp. 13-14.)

78/657 Germany/Italy *German and Italian Research Co-operation* (*Supersonics, Coupled Engine Installations, Timber*). (Inter. Avia., No. 768-769, 16/6/41, pp. 10-11.)

78/658 Great Britain *Stresses between Tyre and Road.* (A. N. Markwich and H. J. Starks, J. Inst. Civil Engineers, Vol. 16, No. 7, June, 1941, pp. 309-325.)

78/659 Great Britain *Early Application of Engineering to the Warming of Buildings.* (A. F. Dufton, Engineer, Vol. 171, No. 4,460, 4/7/41, pp. 4-6.)

78/662 Great Britain 1,000 *Kw. Windmill.* (The Engineer, Vol. 172, No. 4,462, 18/7/41, p. 43.)

78/663 Great Britain *Compaction of Cohesionless Foundation Soil by Explosives.* (A. K. B. Lyman, The Engineer, Vol. 172, No. 4,462, 18/7/41, pp. 45-46.)

78/664 Great Britain *The "Airgraph" Letter Service.* (Engineer, Vol. 152, No. 3,938, 4/7/41, pp. 7-8.)

78/665 Great Britain *The Automatic Adjustable Blade Water Turbine.* (R. V. Terry, Engineer, Vol. 152, No. 3,938, 4/7/41, pp. 17-20.)

78/666 Great Britain *Characteristic Design Factors for Propeller and Kaplan Turbines.* (J. R. Finniecombe, Engineering, Vol. 152, No. 3,939, July 11th, 1941, pp. 21-24.)

78/667 Great Britain *Temperature Tests on Motor Omnibus Brake Drums and Tyres.* (Engineering, Vol. 152, No. 3,939, 11/7/41, pp. 38-40.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
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(Prepared by R.T.P.)

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Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automobile Industries.
Autom. Tech. Zeit. ...	Automobiltechnische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Elektroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.

J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J.S.A.E.	Journal of Society of Automotive Engineers.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Veröffent (Siemens)	Veröffentlichungen aus dem Gebiete der Nachrichtentechnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatshefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für das gesamte Schiess- und Sprengstoffwesen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

Some Problems of Dive-Bombing. (M. P. Solovyev, Air Fleet News, U.S.S.R., Vol. 23, No. 4, April, 1941, pp. 317-322.) (94/1 U.S.S.R.)

Two methods are available for dive-bombing, known respectively as bombing by instruments and bombing by sight.

The first method calls for an instrument-controlled flight path up to the point of release. Since, however, considerable error is involved in the transition to the dive on the target, the method will still generally require correction by sights. Corrections are also necessary for the deviation of the actual conditions from those on which the calculated flight path is based. It would be possible to construct a cam mechanism performing the wind correction continuously during flight. Alternatively it is possible to construct a flight trajectory from any point of which the bomb is sure to hit the target, and construct the necessary instruments for controlling this path.

" Sight bombing " depends on determining the velocity vector of the bomb in relation to the target, the bomb being released when the vector is directed on the target. Dive-bombing sights with automatic wind correction already exist.

Ultimately a combination of the two methods appears to be likely, by which the aircraft is directed to the point of diving by instrumental means, and the point of release of the bomb determined by the sights. Detailed analysis of the requisite operations and the theory of the methods is given in the article.

German Shelter Buildings. (Inter. Avia., No. 676, 7/6/41, p. 14.) (94/2 Germany.)

From press illustrations, a new development trend in the German air raid precautionary measures can be recognized: The construction of underground air raid shelters is supplemented by the erection of entire air raid shelter buildings. These edifices appear to be characterized by especially solid roofs, the substitution of loophole-resembling slots for the windows, thick walls, and a multitude of exits. The impression is gained that such buildings are erected mainly in suburbs and smaller localities; they are several storeys high and serve exclusively to shelter the inhabitants of the surrounding districts in the event of air raids.

Electrical Operation of Time Fuses for Shells. (G. Grotsch, Z.G.S.S., Vol. 36, No. 7, July, 1941, pp. 135-137.) (94/3 Germany.)

Purely chemical time fuses for A.A. shells are not satisfactory, since the rate of burning is affected by atmospheric conditions, especially at high altitudes.

Clock-work fuses do not suffer from this defect but are complicated and expensive. The author describes a number of proposals for fuses, some of which operate partly electrically and partly mechanically, whilst the final proposed design is operated purely electrically without any moving parts.

In the " mixed " design, the acceleration of the shell causes a plunger to pass through a coil and generate a current which charges two condensers equally. These condensers are connected in opposition across a spark gap in vacuum, whilst one of the condensers is provided with a high resistance leak. A potential difference thus gradually builds up across the vacuum and the spark passes when the breakdown value is reached.

In the purely electrical version, the current for charging the condensers is provided externally by the passage of the shell through a coil surrounding the muzzle of the gun.

Some of the difficulties which will have to be overcome before electrically-operated fuses can compete with existing designs are briefly discussed by the author. The great simplicity of a purely electrical device for time fuse operation will deserve the close attention of armament research.

Aerial Barrages (Barrage Balloons, Aerial Mines and Kites). (L. Schuttel, published by Lehmann, 1939.) (94/4 Germany.)

According to the author, a balloon barrage was first employed by the Italians for the defence of Venice in 1916 and some account of the development by France and Great Britain during the concluding stages of 1914/18 war is given. The author's conclusions on the value of such barrages under modern conditions are mainly based on Air Commodore Hearson's lecture to the United Services Institution and the diagrams illustrating various arrangements of the individual balloons in order to protect targets of different types are all taken from this source. The aerial mine, *i.e.* a barrage balloon containing H.E. is also mentioned as a British proposal. It appears that Germany has made some experiments with kites as an alternative to balloons. At high wind speeds ($>$ 10 m./sec.) the tension on the balloon cable becomes excessive and at the same time the cable becomes inclined to such an extent that the value of the barrage suffers. Under these conditions kites give more satisfactory results. The launching of a kite presents certain difficulties which, according to the author, can be overcome by catapulting or utilising rocket propulsion.

Two photographs show the assembly of a German barrage kite whilst a series of ten photographs illustrate features of a German Mobile Balloon Unit. These are of possible interest.

At the time the book was written, it appears that aerial barrages in Germany were limited to the defence of small targets such as the Leuna Chemical Works.

Italian Verdict on the Soviet Air Force. (Inter. Avia., No. 772-773, 15/7/41, pp. 21-22.) (94/5 Italy.)

According to the Italian estimate, the Soviet had about 50 more or less uniformly organized Air Divisions ready for active service at the beginning of the hostilities; each of these divisions consists of from three to five Air Regiments, making a total of approximately 15,000 first-line aeroplanes, of which 30 per cent. are in the reserves. Divided by classes, the total is composed of 45 per cent. heavy and light bombers, 40 per cent. fighters and long-range interceptors, and 15 per cent. reconnaissance and naval air arm types. Before the outbreak of war, the Russian Air Force was divided into two sections, namely, two-thirds composing the Western Air Force, *i.e.* the air formations in European Russia, the remainder the Eastern Air Force, *i.e.* the Air Formations in Asia and the Far East.

The Naval Air Service is characterized by a special organization inasmuch as it is sub-divided into Brigades, Groups and Squadrons; this division varies according to the Naval Command, of which there are four, namely the Baltic, Black Sea, Arctic and Pacific Fleets. By careful calculation a Naval Air Arm strength of about 500 aeroplanes is reached. The Soviet Union possesses three aircraft carriers with displacements ranging from 10,000 to 15,000 tons, as well as three Naval Air Arm tenders.

Until a few months ago, the Russian Air Force had no dive bombers at its disposal at all, and the realization of the necessity to develop this weapon is stated to be of only very recent date.

According to the Italian source, Russia's fighters and long range interceptors are good, reconnaissance and naval air service mediocre, whilst the heavy bombers are unsatisfactory.

The Russian Aircraft Industry and Flying Equipment. (Inter. Avia., No. 770-771, 27/6/41, pp. 1-8.) (94/6 U.S.S.R.)

It goes without saying that the Russian aircraft industry is controlled by the State. From a Department of the Aircraft Industry, originally headed by a Director-General, a separate Soviet Commissariat has meanwhile been formed; its present connections with the Commisssariat of the Heavy Industry are not fully known. The technical sub-division of the administration of the aircraft industry was made on the following pattern: The ZAGI, the aero- and hydrodynamic central research institute, was created in 1918; the ZAIM, the corresponding research centre for the development of aircraft engines, created in 1930; the VIAM, which was organized in 1932 and is charged with testing and accepting the equipment.

It is not possible to state how many plants the Russian aircraft industry possesses at present. Estimates of its production capacity, too, differ greatly. A comparatively short while ago Swedish sources cautiously calculated a monthly output rate of 500 aeroplanes of different types and classes. The plants are scattered over the entire country.

Most of the Soviet Aircraft types which saw service in the Spanish Civil War and in the Russo-Finnish conflict are still among the first-line equipment of the U.S.S.R. Among the fighters operating in Spain and Finland, the I.15 and I.16 were the two best-known models; however, the former, a strutted biplane, strongly resembling earlier Breguet designs, can hardly be counted among first-line aeroplanes to-day. The I.16 (Rata) single-seater fighter is powered with an M-25 nine-cylinder radial engine of 750 h.p. (Wright Cyclone built under licence) and is credited with a maximum speed of 285 m.p.h. (460 km./h.), a ceiling of 31,500 ft. (9,600 m.), and is said to reach 16,400 ft. (5,000 m.) in 6½ mins. The stubby form of the fuselage strongly resembles certain American experimental designs and shows that American influence at that period had a marked effect on the products of the industry. The design of the engine cowling

and the radial adjustable cooling air intakes in the frontal area, are the only proof of independent development work. The armament of the I.16 is variously given as four or even only two machine guns and was considered inadequate already at the time of the war in Spain. The latest Russian fighter aeroplane of which details have reached foreign circles is the I.17, for which the Russian designers sought and found a new pattern in the Vickers Supermarine " Spitfire." The I.17 is a cantilever all-metal low-wing monoplane; wing in three sections, centre portion sheet-covered. Outer panels as well as ailerons and tail surfaces fabric-covered; fuselage a metal monocoque. It is powered with the M-100 liquid-cooled twelve-cylinder in-line engine of 860 h.p. which was developed from the French Hispano 12Y. Judged by modern standards the armament is weak and consists of four wing machine guns firing clear of the airscrew circle. Small fragmentation bombs totalling 220 lbs. (100 kg.) can be carried on racks on the underside of the wing. No weight data of the I.17 is available, but the following characteristics are known: Span 33.1 ft. (10.1 m.); length 24.3 ft. (7.4 m.); wing area 190.5 sq. ft. (17.7 m.^{2}). Maximum speed 305 m.p.h. (490 km./h.); cruising speed 273 m.p.h. (440 km./h.); service ceiling 36,000 ft. (11,000 m.); range 500 miles (800 km.). The only known development of the I.17 is a single-seater fighter designated J.P., which has a more powerful armament than the original type, consisting of two cannon in the wing and two machine guns firing through the airscrew arc. The model J.P was also completed in 1937. It is quite likely, therefore, that the fighter formations of the U.S.S.R. have meanwhile been strengthened by later types resembling more or less the designs produced in the United States or European countries.

The initial development of the Russian *bombers* was influenced in a notable manner by the war doctrine of General Douhet which for some considerable time favoured the employment of multi-engined, heavily-armed giant bombers. The foundation stone of the Russian bomber formations was laid with the construction of the ANT-6 four-engined bomber re-named later *T.B.3*. The T.B.3 is a cantilever low-wing monoplane whose wings and fuselage consist of a metal frame with corrugated sheet skin. Power plant: Four M-17 liquid-cooled twelve-cylinder " Vee " engines of 600 h.p.; the armament consists of four twin machine guns; normal bomb load 3,300 lbs. (1,500 kg.), gross weight 33,000 lbs. (15,000 kg.); maximum speed 126 m.p.h. (200 km./h.); ceiling 16,400 ft. (5,000 m.). By the installation of more powerful engines of the type M-34 and by improving the shape of the fuselage, a development of the T.B.3 was produced in 1936 which, while retaining the same dimensions, had a considerably higher performance. This type was designated T.B.5 but was soon replaced by the T.B.6. The landing gear of the T.B.6 was semi-retractable into wheel fairings and moved backwards and upwards; normal bomb load 6,600 lbs (3,000 kg.). Fitted with four M-34 liquid-cooled engines of 950 h.p. each, the T.B.6 had a maximum speed somewhere between 220 m.p.h. and 250 m.p.h. (350 and 400 km./h.), a cruising speed of 186 m.p.h. (300 km./h.) and climbed to 13,000 ft. (4,000 m.) in 24 mins. Since 1935 the men responsible for the Russian bomber formations have been showing increasing interest for the twin-engined medium bomber. The first type of this class was developed by the well-known designer Tupoleff and proved its worth in the Spanish War. The Z.K.B.26 showed a considerable resemblance to the Martin 139 twin-engined bomber developed in the U.S.A. and is powered either with two M-100 liquid-cooled twelve-cylinder engines of 850 h.p. or two 750 h.p. Wright Cyclone nine-cylinder radials. The armament is composed of a machine gun station in the transparently-covered hemispherical fuselage nose, a machine gun station in the top of the fuselage, as well as a machine gun firing through the fuselage floor; normal bomb load of 1,400 lbs. (640 kg.). The same model was produced also with the M-85 14-cylinder twin-row radial of 1,000 h.p. (Gnome & Rhône 14K built under licence) and in this version had a somewhat higher speed and carried an increased bomb load of 2,200 lbs. (1,000 kg.). With the Z.K.B 26 there

began a new phase in the tactical organization of the Soviet-Russian bomber formations: While the heavy multi-engined bombers of the period from 1932-1937 or their developments still represented the backbone of the Russian Air Force, the main weight of the Russian production shifted gradually to the construction of high-speed medium bombers first conceived by the Americans.

The Russian Air Force. (Luftwissen, Vol. 8, No. 7, July, 1941, pp. 206-208.) 94/7 Germany.)

The following types are referred to and partly illustrated:

FIGHTERS.

Biplanes: I.15, I.15 Cis, I.153.

Low-wing Monoplanes: I.16 (Rata), I.61 (I.200), I.17 (2KB.26), I.26.

The majority of the squadrons are composed of I.15, I.15 Cis and I.16. These may be regarded as obsolescent.

I.61, I.17 and I.26 are more modern, but only relatively few of these types have been encountered so far. I.61 fitted with a 12-cylinder V engine and is stated to have a good performance.

BOMBERS.

S.B.2, S.B.3, D.B.3, D.B.3A, P.2 (BB.22), TB.3 and TB.6.

The majority of the aircraft seem to consist of S.B.2, S.B.3 and D.B.3. S.B.2 is a copy of the original Martin (U.S.A) and S.B.3 represents an improved version of the same type (higher horse-power).

These machines are mid-wing monoplanes.

The D.B.3 is a low-wing monoplane fitted with two air-cooled twin radials, rated at 950 h.p. each at 10,000 ft. It has a crew of three or four and is fitted with three mobile machine guns. A range of 1,200 km. with a bomb load of 2,500 kg. is claimed (max. speed 270 m./h. at 10,000 ft., rate of climb to this altitude 1,000 ft./minute).

D.B.3A is the same machine fitted with a longer nose.

P.2 is a light twin-engined low-wing dive bomber, fitted with twin rudders.

T.B.3 is a four-engined heavy bomber which may be regarded as obsolete. A more modern version (T.B.6) is stated to be available only in small numbers.

NAVAL AIRCRAFT.

Single-engined flying boat M.B.R.2.
Twin-engined flying boat M.D.R.6.
Ship-borne K.O.R.1.
Long Distance Reconnaissance flying boat G.S.T. (Consolidated 28).

According to Soviet claims, a labour force of 500,000 produced 12,000 aircraft of all types during 1940.

At the outbreak of the war, between 6,000 and 10,000 aircraft are estimated to have been available on the Russian side.

Self-Catapulting Autogyros for the Protection of Cargo Vessels. (P. Thomas, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 69-70, 233.) (94/8 U.S.A.)

Present engineering knowledge indicates that it would be possible to build an autogyro carrying pilot and observer, two depth charges, two-way radio, smoke screen apparatus and have a reasonable cruising radius. The speed is estimated at 120 m.p.h., 14,000 ft. ceiling and 800 ft./min. rate of climb. Such a machine would only require a platform 50 ft. wide and 80 ft. long for landing and take-off, and such a structure could be provided on the stern of most cargo vessels. The new Pitcairn autogyro has manual control for pitch of rotor blades, so that quick descents from a height of 10 to 15 ft. can be made. This should allow safe deck landings even in a rough sea. It is stated that the firm has also developed a landing device for making the aircraft fast immediately it touches the deck. (An arresting gear is not needed

as there is no forward run.) By means of such aircraft the seas could be patrolled at some distance from the convoy and submarines spotted. Depth charges could then be used or a smoke screen laid. It is stated that the feasibility of the scheme has been demonstrated by hill-top landings in very disturbed air.

Interstate Hydraulic Machine Gun Charger. (Aero Digest, Vol. 31, No. 1, July, 1941, pp. 206-209.) (94/9 U.S.A.)

This new unit is a compact device which not only charges the machine gun but also re-charges it when it has jammed, hit a dud shell, or stopped firing for other reasons. It is located so that the pilot or gunner can operate the bolt mechanism of the gun, ejecting the old shell in one direction of its movement and throwing in a new one at the end of the return stroke, the complete cycle of operation taking a fraction of a second. The charger is controlled merely by flicking a valve handle and will perform efficiently at temperatures as low as $-40°$.

The charger consists of a cylinder assembly and two supporting brackets which attach directly to the side of the gun. An electrical contactor box containing two sets of contact points is optional equipment and mounts on the rear support. One set of points makes contact each time the gun fires, causing a light to blink on the instrument panel as long as the gun is firing and indicating the position of the bolt while the gun is jammed or charging. The other set of points makes contact every tenth time the gun fires and is for the purpose of operating a rounds counter on the instrument panel, indicating at all times just how much ammunition is left.

The hydraulic connection can be made at either top or bottom of the forward end of the cylinder, the unused opening remaining plugged.

A conical pin, spring-mounted to the cylinder, engages in a socket on the front support, while the housing on the rear end of the cylinder assembly attaches on to the rear support. The cylinder assembly is easily and instantly removed from the gun by releasing the latch and safety and lifting it from the supports; thus the cylinder assembly can remain as part of the aeroplane's hydraulic system while the gun is removed for service or repair.

Operation is effected by hydraulic pressure pushing a piston and rider toward the rear against the pressure of springs. As the rider moves, it engages the gun bolt stud and moves it to the rear position, at which time a latch in the gun charger engages the rider. When the hydraulic pressure is released and the cylinder is open to discharge, the springs move the piston toward its forward position but the rider which holds the gun bolt stud remains latched in its rear position until the last $\frac{1}{4}$ in. of piston travel. This last part of the piston travel releases the latch allowing the gun bolt stud and rider to return rapidly to the forward position.

The charger is designed to stand extreme vibration and hammering and is suitable for operation on either 800 or 1,500 lb. pressure systems, yet will continue to operate when the hydraulic pressure drops as low as 250 lbs./sq. in. It has been tested to 3,000 lbs./sq. in. pressure and a fatigue test of 5,000 operations has been run with no indication of failure in either test.

All parts are interchangeable. The complete assembly including the contactor box weighs three lbs. It can be mounted on either side of the machine gun and is especially applicable to machine guns mounted in wings or other remote locations.

Remarks on the Analogy Between Heat Transfer and Momentum Transfer. (L. M. K. Boelter and others, Trans. of the A.S.M.E., Vol. 63, No. 5, July, 1941, pp. 447-454.) (94/10 U.S.A.)

This paper presents an extension of Von Kármán's analysis of heat transfer to fluids in closed conduits, based on the analogy between heat transfer and

momentum transfer. For a particular ideal system, an expression for the temperature distribution in a fluid in turbulent motion being heated or cooled inside a circular pipe is derived and a relation is obtained between Nusselt's modulus and the pipe-friction factor for " isothermal " heat transfer. This equation is extended to apply in cases in which the physical properties of the fluid vary across the section of the pipe. The apparent variation of the dimensionless distance parameter y^+ with ratio of wall viscosity to laminar sub-layer viscosity and Reynolds' number is obtained. A comparison between the equation developed in the paper and the Nusselt empirical equation, including the constants evaluated by Dittus and Boelter, is made.

The Propagation of Pressure Fluctuations of Large Amplitude in Air Columns. (L. J. Kastner, Phil. Mag., Vol. 32, No. 212, September, 1941, pp. 206-224.) (94/11 Great Britain.)

The results of the investigation indicate, within the scope of the experiments described, that the velocity of propagation of pressure waves in air produced in a pipe excited by a piston is independent of the frequency, when the peak amplitude of the free vibration corresponds to a pressure of a few inches of mercury, and the number of vibrations varies betweeen 20 and 150 per second. Under the above conditions the velocity of propagation appears to diminish at a greater rate with decrease of pipe-diameter than for cases when the amplitude is very small.

The waves generated in the pipe are attenuated as they travel along the pipe, and are also reduced in amplitude on reflexion from the ends of the pipe. For pipe-lengths up to ten feet the attenuation constant appears to be unimportant compared with the open-end and closed-end reflexion coefficients, and the product of these latter coefficients does not vary greatly with changes of pipe diameter.

On Acoustically Effective Vortex Motion in Gaseous Jets. (P. Savie, Phil. Mag., Vol. 32, No. 212, September, 1941, pp. 245-252.) (94/12 Great Britain.)

Tollmien's general criterion of instability of one-dimensional fluid motion is applied to the problem of sound sensitive plane jets. Bickley's formula is inserted into Tollmien's disturbance equation and stream function, wave-velocity, and wave-length are found. The stream-line representation shows good qualitative agreement with G. B. Brown's photographs of smoke jets. Furthermore, a formula connecting the frequency of the sound with either of the two proper values of the disturbance equation is derived, which is in fair agreement with G. B. Brown's measurements on edge-tones. A brief explanation of the phenomenon of sensitive jets is given.

The Production of Waves by the Sudden Release of a Spherical Distribution of Compressed Air in the Atmosphere (Blast Waves). (J. J. Unwin, Procs. Roy. Soc., Vol. 178, No. 973, 12/6/41, pp. 153-170.) (94/13 Great Britain.)

An attempt has been made to develop a method for dealing with solutions of problems connected with the production of waves by spherical concentrations of compressed air. Starting from the general equations for three-dimensional spherically symmetrical flow in a homogeneous compressible medium having constant entropy everywhere, a process has been devised to apply step-by-step calculations over small intervals of time to investigate the general features of such a motion. A complete solution has been worked out in one particular case for a not very intense initial distribution of pressure, and various indirect checks have indicated that the results are reasonably accurate.

The method is applicable to any spherically symmetrical motion up to such a time as the formation of a shock wave takes place and then fails owing to the assumption of constant entropy.

Pitch Control for Co-axial Counter Rotating Airscrews (Fairey Patent 534,528). (Inter. Avia., No. 767, 7/6/41, p. 6.) (94/14 Great Britain.)

The British patent No. 534,528 has been granted to the Fairey Aviation Co., Ltd., of Hayes, Middlesex and covers an interesting arrangement for the automatic control of the angle of incidence of oppositely rotating co-axial controllable pitch airscrews mounted in close tandem. A vane, pivotal about a vertical axis in the vertical plane of the axis of the airscrews, is mounted on the fuselage forward of the cockpit and automaticallly adjusts itself to the direction of the airscrew slipstream. By means of sleeve valves in the mounting of the vane, two engine-driven pumps are controlled which change the blade angle until the twist component of the slipstream as measured by the vane disappears. The patent specifications cover electrical, hydraulical or mechanical control of the mechanism.

Reproduction of Work Templates by the Electrolytic Press. (Aviation, Vol. 40, No. 4, April, 1941, p. 113.) (94/15 U.S.A.)

Said to be faster and more economical than the photo-loft-template process, the new method is simple and the materials used are standard in most plants. A master layout is scribed from an Engineer's drawing on a galvanized iron sheet about .040 in. thick, one face of which has been prepared with a special coating of insulating paint. Layout thus formed is sprayed with a transfer solution and the wetted surface is pressed into firm and uniform contact with a copy plate in a specially built press. An electric current passing between the two plates results in the layout of the master plate being transferred instantly to the copy plate. Given a thin protective coating, the copy plate is then ready for immediate use by the template cutters. Total time required from the moment the copy plate is placed in the press with the master plate until it is washed, dried and ready for the template department is not more than 5 min.

Hamilton Standard Airscrew Laboratory. (Inter. Avia., No. 772-773, 15/7/41, pp. 10-12.) (94/16 Switzerland.)

The laboratory includes the following equipment:

A *cold room* affords facilities for testing airscrews at temperatures as low as 50 deg. F. below zero; a *whirl rig* serves for test runs at excess rotational speeds up to 4,000 r.p.m., the airscrew being driven by an 185 h.p. engine. The air is supplied to the test chamber by a blower at rates up to 7,000 cu. ft. per min. and can be heated to 150 deg. F. Besides the air inlet, an automatic stoker is mounted, which by means of compressed air projects sand, gravel, cinders, water or similar materials at the airscrew. This installation is used for the study of erosion of the airscrew or the control mechanism, which occurs chiefly in tropical regions.

To make possible the measuring of the dynamic unbalances resulting from differences in weight, axis positions and centre of gravity paths of the blades, the bearing system of the airscrew shaft is pivoted about an axis perpendicular to that of the shaft, so that it is oscillated by the dynamic unbalance of the airscrew. These oscillations are transmitted to the measuring device by pick-ups in the form of alternating current.

For the separation of the dynamic unbalance from the aerodynamic unbalance resulting from differences in the blade shapes or the angles of incidence, an entirely new course is adopted. At a small distance back of the airscrew there is a screen-mesh diaphragm mounted on a steel structure. This diaphragm, which is pivoted about a vertical axis, is made to oscillate by differences in the thrust moments of the individual airscrew blades; these oscillations are opposed by the inertia of the diaphragm structure.

The theoretical studies justified the expectation of a measuring accuracy that would correspond to blade pitch variations of 0.015 deg; however, due

to disturbing interference of vibrations of the mounting base and unsteady airflow only angle differences of 0.1 deg. are revealed. By improving the airflow conditions and the installation of honeycomb straighteners and baffles efforts are made to eliminate these influences and to improve the measuring accuracy. However, the influence of a blade angle difference of 0.1 deg. is negligible in normal flight, compared with the dynamic unbalance considered as permissible where it results from inaccurate mounting of the airscrew on its shaft.

U.S. Army Air Corps New Wind Tunnel. (Inter. Avia., No. 772-773, 15/7/41, p. 14.) (94/17 U.S.A.)

The new 20 ft. tunnel is destined less for new development work than for studies of practical problems arising in air force operation. The test section will be housed in a reinforced concrete building measuring 108 ft. in length and 62 ft. in width and capable of withstanding a differential pressure of 400 lb./sq. ft. The model is connected with scales in the balance room at the top of the test building by means of three struts and can be regulated by remote control. The measuring values will be transmitted to the control room also by remote control. The control room is sealed off from the tunnel and is both air-tight and sound-proof; favourable working conditions are maintained by means of an air-conditioning plant. Windows enable the model to be observed from the control room. The two fans of 40 ft. diameter have 16 blades each. The driving motor, the biggest wound-rotor induction motor ever built, develops 40,000 h.p. and is housed in a separate building; it is connected to the two fans by 120 ft. of shafting. The speed of the motor can be regulated between 37 and 297 r.p.m. In order to reduce the waste of electrical energy when the motor is delivering only part of its full output, the current is led through a system of two motor-generator sets. The motor assembly was scheduled to be ready for operation by July 1st, 1941.

Synthetic Resins as Aircraft Construction Materials (Part II). (Inter. Avia., No. 774, 23/7/41, pp. 1-5. Part I, No. 772-773 Notice No. 28,502.) (94/18 Switzerland.)

(1) Properly selected synthetic resins have the following properties which make them suitable for the aircraft industry: Good mouldability, low specific weight, smooth surface, low inflammability, resistance to chemicals and bacterial growths, low hygroscopicity, great energy absorption for oscillation damping, manufacture from non-strategic raw materials.

(2) Synthetic materials suitable for the manufacture of entire airframes without stiffening additions are not known at present.

(3) The strengthening of synthetic resins to the values required for the manufacture of aircraft by means of fabric fillers is not excluded; however, materials of this class ready for use are not yet available.

(4) Wood improved by means of synthetic resins and plastics strengthened by means of wood layers are widely and advantageously adopted to-day.

(5) Methods and installations for the industrial manufacture of airframe components from compound wood/plastics materials are available.

(6) The " plastics aircraft " available to-day are made exclusively of wood improved by synthetic resins on the principles of conventional plywood construction under the application of the processes in question for the manufacture of shell components.

(7) The development of a method for the construction of wood/plastics aircraft in which the properties of the new compound materials are fully exploited with a view to reducing the manufacturing time, the quantity of material needed and the weight, and to adapting them to the static and aerodynamic requirements, is still in its infancy.

U.S.A. Altitude Equipment. (Inter. Avia., No. 774, 23/7/41, pp. 15-16.) (94/19 U.S.A.)

Particular value is attached to the improvement of altitude equipment for the single-seater and two-seater aircraft crews which for technical reasons cannot be provided with the advantages of the pressure cabin. For example, a newly developed electrically heatable underwear suit of latex which together with boots and gloves weighs only 7 lbs., can be heated by 12-volt current from the electrical system of the aeroplane, and is still comfortable at temperatures as low as 60 deg. F. below zero, is now being tested. The main advantage of this garment, besides its low weight, is the flexibility of the fabric which is stated not to handicap the movements of the crew in any way. Moreover, the B-L-B oxygen mask introduced as standard equipment in the U.S. Army Air Corps, has been improved by designing a lighter and smaller mask and replacing the rubber breather bag by a flat breathing reservoir. This reservoir is not directly connected with the mask but can be accommodated in a chest pocket of the flying suit, so that the crew is not encumbered by the flopping of the breather bag following each head movement. Other experiments are far advanced with bullet-proof low-pressure oxygen tanks; these tests appear to have been made on the basis of experience collected in the European war.

Line of Development of Italian Aircraft Design. (*Lecture to the Lilienthal Society, Berlin.*) (A. Guglielmetti, Luftwissen, Vol. 8, No. 7, July, 1941, pp. 209-215.) (94/22 Italy.)

High speed at high altitude is becoming of increasing importance and is receiving considerable attention by the Italian authorities. It is well-known that speed and wing loading are intimately connected. If the h.p. and propeller efficiency are independent of altitude, theory indicates that the optimum wing loading decreases with altitude. With increased power loading, however, the optimum wing loading at a given altitude increases with the power loading. Unfortunately, the h.p. per propeller blade which can be absorbed at optimum efficiency rapidly diminishes with altitude and flying speed. Thus, at 800 km./h. near the ground, a three-bladed propeller of 3.5 m. diameter can be built to absorb 3,000 h.p. at reasonable efficiency. At 40,000 ft., however, such a propeller will only absorb 450 h.p., without either an increase in Mach Number or in diameter. This shows the need at high altitude of sub-dividing the power plant or driving more than one propeller from one engine. In the latter case the use of contra propellers and gear boxes is receiving attention. At low altitudes on the other hand the construction of several engines driving one propeller is also worthy of consideration. The increasing difficulty of obtaining reasonable propulsive efficiency at high speeds with the orthodox power plant has led to increased attention being given to jet propulsion. The Campini aircraft utilizing the alternation method is stated to have flown successfully. At low altitudes, the air is compressed by the flight speed before entering the engine drive compressor and mixed with the engine exhaust before expulsions in the jet. At higher altitudes, additional heat is given to the air by an auxiliary burner.

As is well known, Italy still utilizes wood to a considerable extent in aircraft construction. Special reference is made to the Zappata method of building fuselage shells by glueing strips of thin veneers (40 m.m. wide, .6 to 2 m.m. thick) on a suitable framework of compressed wood. It is stated that the performance of wooden aircraft weighing up to 20 tons compares favourably with all-metal machines, whilst being much easier to produce. Of interest is reference to an experimental fighter (low-wing monoplane) fitted with a 12-cylinder air-cooled V engine (Isotta Fraschini Delta) of 800 h.p. The wing area is only 14 m.^{2} and the total weight 2,000 kg. On account of its compact size, this machine is stated to have outstanding manœuvrability and requires only $\frac{1}{3}$ of the man-hours of a standard fighter for its production.

As regards equipment, an air intake filter for preventing sand getting into the engine is of interest. Two types have been developed. The first suitable for coarse-grained dry sand consists of a series of deflector plates which cause separation by inertia. These plates are placed in a box below the engine cowling. The second is a filter proper, consisting of two wire gauzes enclosing fine fabric and placed inside the cowling. Provision is made for easy cleaning of the filter before each flight. In the latest type of filter, a whirling chamber causes the heavier particles to separate before the airstream reaches the filter proper.

Problem of Weight Control. (L. R. Hackney, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 134-136, 237.) (94/23 U.S.A.)

The Society of American Weight Engineers was organized about two years ago with the object of a closer relationship between weight engineers and to correlate weight information. With its co-operation of every major aircraft form, a Master Weight book has been compiled and the Army and Navy Standard detail and group statements have been revised. The aircraft structure is sub-divided into seven main groups. The layout for the estimated weights of the wing group and one of its principal sub-divisions is illustrated below, the figures applying to a four engine transport of 40,000 lbs. gross weight.

	Weight.	Arm.	Horizontal Moment.
WING GROUP	3,964.0	453·5	1,798,055
Inner Wing Panel	2,905.0	450.4	1,308,602
Outer Wing Panel	642.0	435·4	—
Tips	25.0	428.0	—
Ailerons	109.0	474.0	etc.
Flaps	283.0	521.0	—
INNER WING PANEL	2,905.0	450.4	1,308,602
Front Beam	286.0	416.0	—
Intermediate Beam	—	—	—
Rear Beam	248.0	479.0	—
Auxiliary Beam...	—	—	—
Ribs	536.0	449.0	etc.
Stringers	—	—	—
Fittings	108.0	448.3	—
Corrugations	369.0	449.8	—
Gussets	—	—	—
Formers...	—	—	—
Channels	—	—	—
Stiffeners	115.0	453·5	—
Angles	—	—	—
Fillers	39.0	449.8	—
Fabric	—	—	—
Metal Covering	668.0	461.0	—
Paint	32.0	449.0	—
Inspection Doors	13.0	474.0	—
Fairing	18.0	434.0	—
Leading Edge	123.0	406.0	—
Hinge and Pins...	—	—	—

Weight control may be divided into:—

(1) Parts entirely within the Design groups control (wing, fuselage, tail, etc.).

(2) Parts partly controlled (fuel system, hydraulic and electrical equipment, armament provisions, etc.).

(3) Parts beyond immediate control (engines and purchased equipment, etc.).

Division (1) amounts to between 35 per cent. and 50 per cent. of the weight empty; (2) 10-15 per cent. and (3) 45-50 per cent. It thus appears that roughly half the estimated empty weight of the aircraft is subject to control by the Weight section. The saving of 1 lb. weight in an aircraft represents a saving of about $10 in manufacturing cost and is worth about $100 a year in pay load to the transport company. A 10 per cent. increase in gross weight means a 25 per cent. increase in power to reproduce the standard take-off, and a 13 per cent. increase in power to obtain the standard rate of climb.

Weight control is thus of the utmost importance. The stress department must be made "weight conscious," and allowance for "unknowns" must be done away with. Progress would be more rapid if detailed weight schedules of all successful models could become generally available.

Weight Economy. (J. E. Ayers, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 138-142, 238.) (94/24 U.S.A.)

The article is intended for new draughtsmen in the Aircraft Industry and he is urged, before the release of any drawings, to consider the following points, amongst others:—

Possible substitution of Al. Alloy for Steel.
,, ,, ,, Mg. Alloy for Al. Alloy.
,, ,, ,, Micarta for Light Alloys.
,, ,, ,, Moulded Plastic.
Can the part be simplified?
,, ,, spot-welded?
Can lightening holes be provided?
Relative advantages of formed and extruded sections and forgings.

Each of the above points are discussed in some detail with examples taken from current aircraft designs. It is interesting to note that due to wear of dies, extruded sections have generally about ten times the tolerance of rolled sheet and this is an argument in favour of formed sections. It is stated that in a recent 6,000 lbs. gross weight aircraft the weight penalty due to oversize of the extruded stringers (bulb sections) amounted to nearly 9 lbs.

Strengthening Aluminium for Aircraft Structures. (K. R. Jackman, Metal Progress, Vol. 40, No. 1, July, 1941, pp. 35-42 and 88.) (94/25 U.S.A.)

A typical modern aircraft weighing 50,000 lbs. gross will have a tare weight of about 27,000 lbs. of which 11,000 lbs. represent engines, propellers, accessories and non-structural furnishing. The remaining 16,000 lbs. of structure will be sub-divided as follows:—

Metal.	Form.	Wing.	Fuselage.	Tail.	Landing Gear.	Controls & Misc.	Total lbs.
Steel	CR-MO	300	200	20	1,000	80	1,600
	Stainless	500	50	—	—	50	600
Magnesium	Castings	—	—	—	—	50	50
Al. Alloy	Sheet	7,000	2,100	800	100	500	10,500
	Extrusions	150	100	50	25	175	500
	Drawn Parts	950	400	100	—	50	1,500
	Castings	—	—	—	—	100	100
	Forgings	150	50	25	100	25	350
	Rivets	250	100	50	—	50	450
Others	All	20	20	20	40	100	200
					Grand Total		15,850

Aluminium Alloys thus account for 13,400 lbs. out of the total of 15,850 lbs. The sheet metal covering wings, fuselage and tail represents the biggest item, *i.e.* 10,500 lbs. The present trend is to use 24S-T Al. Clad. which eliminates

most of the corrosion troubles and very little can be done to strengthen this product still further so as to save weight. It has been known, however, for some time that extrusion and drawn shapes can be considerably strengthened by cold working and although the total weight of products of this type in the aircraft under consideration amount to only 2,000 lbs. this treatment would be worth while provided practical shop procedures can be developed.

The author describes the method adopted by Consolidated Aircraft for pre-stretching structural sections to 3½ per cent. permanent set on the straightening jig at very little extra cost. The gain in ultimate and yield strength of the material is such that a saving in weight of about 10 per cent. results. The reason for limiting the pre-stretching to 3½ per cent. permanent set is mainly the need for retaining sufficient residual elongation to accommodate stress concentration and dynamic load. Greater pre-stretching also increases the amount of rejected material.

Load Carrying Capacity Phenomena of Bearing Surface. (N. O. Tectov, J.S.A.E., Vol. 47, No. 6, Dec., 1940, pp. 497-503.) (94/26 U.S.A.)

The author confines himself to bearing surface under conditions of boundary lubrication or operating in the absence of lubricant. Failure will occur if the areas in contact reach the melting point of the material. Smooth surfaces have larger areas of contact and will therefore generate more heat, *i.e.* their load capacity is less. It has generally been noted that a bearing surface will acquire a high polish just before scuffling occurs, and that such a burnished surface will never carry as much load again as it did while acquiring the burnished finish. For his experiments the author used a so-called " scuffling " machine in which one of the bearing surfaces is stationary whilst its other reciprocates, oil being supplied to the latter at a definite rate. The load on the stationary sample is increased at a steady rate and a time record of its temperature is taken. Considerable benefits were found to result when the bearing area was provided with grove filled with iron oxide.

(It appears that the conditions of this test apply particularly to piston rings.)

Possibilities of Barrel Engines of Small Frontal Area for Aircraft. (E. S. Hall, J.S.A.E., Vol. 47, No. 6, Dec., 1940, pp. 497-503.) (94/27 U.S.A.)

The best engine form for high-speed flying is that having the lowest air drag. According to the author, the following table gives the drag h.p. at 20,000 ft. of various cylinder arrangements for a gross output of 2,000 h.p. in each case (air-speed 400 m.p.h.).

			Frontal Area (sq. ft.).	Drag (h.p.).
Twin row radial,	18	cylinders ...	16	373
V Tandem	24	,, ...	12	280
H Type	24	,, ...	10	233
Barrel Type	18	,, ...	6	140

In the barrel engine, the piston displacement varies as (engine diameter)^3 and it is possible to crowd in as much as 25,000 cubic inches piston displacement into a cowling diameter of 50 in. normally housing a 1,000 h.p. radial of 2,000 cubic inch displacement.

Three type barrel engines are investigated by the author in greater detail:—

(1) Swash plate with slipper.
(2) Cylindrical cam mechanism with rollers in the piston.
(3) Wobble plate.

The Wobble plate mechanism is considered the most promising and an experimental unit with a floating wobbler designed by Almen was tested by the U.S.A. army authorities.

This design together with later improvements is illustrated.

It is estimated that an 18-cylinder two-stroke Diesel designed on these lines (displacement 5,500 ci) should develop about 1,700 b.h.p. without much development work 80 lb. per sq. in. b.m.e.p.). Ultimately 5,000 h.p. should be possible for a frontal area of not more than 7 sq. ft.

Application of Aluminium in Diesel Engine. (F. Jardine, J.S.A.E., Vol. 47, No. 6, Dec., 1940, pp. 520-525.) (94/28 U.S.A.)

Conventional high-speed Diesel engines for motor transport, weight about 20 lb. per h.p. By using aluminium for the cylinder heads, cylinder block, crankcase, piston, gear covers, flywheel housing, etc. the weight can be reduced to about 10 lb. per h.p. with practically no change in design or manufacturing practice. Further reduction in weight is possible by supercharging and the author describes in detail some design features of a 160 b.h.p. unit weighing as little as 7.8 lb. per h.p. (b.m.e.p. 160 lb. per sq. in. at 2,400 r.p.m.).

Experience in long distance haulage in the U.S.A. has shown that 1 lb. saved in dead weight of a truck is worth about 1 dollar a year (mileage 100,000). The extra cost of 1 lb. light alloy engine amounts to about 30 cents. per lb. of weight saved, the light-weight engine is then definitely an economic proposition under these conditions.

(In aerial transport 1 lb. saved corresponds to about 100 dollars in pay load.)

Effectiveness of the Burning Process in Non-Knocking Engine Explosions Based on an Analysis of Flame Picture and Pressure Data. (L. Withrow and W. Comclius, J.S.A.E., Vol. 47, No. 6, Dec., 1940, pp. 526-548.) (94/29 U.S.A.)

The author carried out experiments on a CFR engine fitted with a quartz window and carbon stack electric indicator. Flame motion pictures and pressure records were taken simultaneously and the author's attempt to estimate the heat loss by a careful analysis of five different engine explosions, in two of which benzene was the fuel, whilst in the other three the engine was operated with isooctane. The compression ratio was 4.8 and the piston speed 600 ft. per minute throughout (900 r.p.m.). The authors conclude that under the conditions of their experiments only 81 per cent. of the energy liberated according to thermo-dynamic data is accounted for by the pressure record. Theoretical rates of combustion (mass basis) required to produce the experimental pressure record are in agreement with the observed rates during the inflammation of the first 10 per cent. and the last 50 per cent. of the charge. Over the region of maximum rate of inflammation (corresponding to about 30 per cent. of the charge burnt) the theoretical rate is, however, only about half the practical rate as estimated from the flame photographs. From this it is concluded that most of the energy loss of the charge occurs over the period 5°-10° of crank angle after T.D.C. and before maximum pressure is reached. The complete elimination of the loss could raise the indicated m.e.p. by 20 per cent.

The most obvious explanation of the energy loss observed is that it is due to heat lost to the wells of the combustion chamber; other possible explanations are:—

(1) Incomplete combustion in the flame front, *i.e.* inflamed gases continue to liberate energy for some time after the flame has passed.
(2) Dissociation of CO_2 and H_2O to a greater extent than assumed on the basis of thermo-dynamic data.

In the discussion of this paper, reference is made to some indicator diagrams taken on a C.F.R. engine by the M.I.T. which show that the experimental indicated m.e.p. varied between 80 and 85 per cent. of the values calculated with the help of existing thermo-dynamic data. The effectiveness of combustion is thus of the same order as that estimated from the flame photographs.

Ford Aircraft Engine. (Inter. Avia., No. 774, 23/7/41, p. 14.) (94/30 U.S.A.)

The engine is a liquid-cooled Vee-12 type and is expected to have a take-off output of 1,800 h.p. at 3,000 r.p.m. and an altitude output of 1,500 h.p. at 30,000 ft. Its weight is estimated at 1,600 lb., working out at less than 1 lb./h.p.

The exhaust gases of the two cylinder banks are fed to a turbine through a horizontal collector each; they are exhausted centrally to the rear after passing through the turbine. The blower (two-stage ?) driven by the exhaust gas turbine is arranged beneath the crankcase and supplies the compressed air through a vertical duct to an intercooler located between the two cylinder banks and projecting somewhat above the latter at the rear; thence it is fed to the cylinder air inlets. The crankcase and the cylinder banks are an integral casting of aluminium alloy. The cylinder liners are not in contact with the coolant and are therefore of the " dry " type. They are of centrifugally cast steel and are free of any kind of flanges or bosses in order to avoid distortion by heat. Each cylinder head contains two inlet and two exhaust valves which open simultaneously at the top stroke position of the piston before the latter's compression stroke; the arrangement serves for the scavenging of the combustion chamber. Each cylinder bank has two overhead camshafts whose cams are directly on the valve stems. The engine is stated to be designed for fuel of 100 octane rating which is injected directly into the combustion chamber. The crankshaft is of the six-throw type and is made of centrifugally cast steel by the long-proven Ford method; each throw carries a floating big-end bearing to which are attached the connecting rods of an opposite pair of cylinders.

Spark Plug Threads in Light Metals. (Automotive Industries, Vol. 85, No. 3, 1/8/41, p. 48.) (94/31 U.S.A.)

When a spark plug has to be secured into the wall of a cylinder or cylinder head cast of a light alloy, it is customary to insert a bushing of some stronger material. To obviate the need for such a bushing, a German firm has patented a special thread for spark plugs and spark-plug holes. Both the spark plug and the hole for it are cut with a relatively coarse V thread, the thread in light metal has the top half removed, and the thread on the plug groove is filled up with metal to half its depth. Only the top half of a normal V thread is used on the plug and the bottom half in the light metal part. For a given radial depth of thread this gives a much stronger thread in the light metal part.

Spark Plug Indicator for Navy Planes. (Autom. Ind., Vol. 85, No. 3, 1/8/41, p. 41.) (94/32 U.S.A.)

The Bureau of Standards, which during the World War developed an improved grade of porcelain for use in spark plug insulators, has completed tests for the Navy on a dashboard indicator by which an aeroplane pilot can tell at a glance whether any particular one of the spark plugs of his engine is functioning properly. If the indicator shows the plug to be too hot, it may be due to the surface of the insulator being fouled with lead. This can be corrected by reducing the richness of the fuel mixture. If, on the other hand, a plug shows up too cold, it indicates the presence of carbon deposit on the insulator. This can be corrected by increasing the speed of the engine, thereby raising the temperature of the insulator and burning off the carbon.

The Brown Boveri Exhaust Driven Supercharger for Aero Engines. (E. Klingelfuss, Flugwehr and Technik, Vol. 1, No. 4, April, 1939, pp. 107-111.) (94/34 Switzerland.)

The Brown Boveri Company has had considerable experience in the supercharging of large four-stroke Diesel engines by exhaust-driven blowers (Buchi System). In such engines, the maximum exhaust temperature is of the order of 600°C. only, whilst considerable benefit arises from the fact that the engine

can be scavenged with cold air without difficulty. The problem is much more difficult in the case of the spark-ignition aircraft engine since the exhaust temperature is much higher (900-1,000°C.) and the carburettor generally employed renders scavenging without loss of charge very difficult. Since no blade materials are available for exhaust temperatures of 1,000°C., Brown Boveri have adopted a method of air cooling for the blades, the latter being subjected alternately to exhaust and air streams. In this way the blade temperature can be kept at 600°C., but the bulk and weight of the unit naturally increases. A turbo installation suitable for one bank of an 800 h.p. V engine is illustrated. Two of these units, one on each bank, would be fitted and running at a maximum speed of 24,000 r.p.m. ground level pressure can be maintained up to 30,000 ft. Each turbo has two exhaust inlets, placed 180° apart and discharges axially into the atmosphere. The blower intake is on the opposite side to the exhaust discharge. It is stated that each turbo blower weighs approximately 90 lbs.

In developing the turbo blower, a special test stand was employed, the exhaust gases being produced by means of a special burner operating in the requisite air pressure.

The author is of the opinion that turbo supercharging for aircraft engines is only feasible if combined with scavenging and this entails the employment of petrol injection instead of a carburettor.

Two advantages of turbo blowers for aircraft are often overlooked. It is unaffected by the provision of constant-speed V.P. airscrews (the mechanically-driven blower requires a gear-box under these conditions) and the installation acts both as a flame damper and exhaust silencer.

Aero Engine Research and Development. (C. L. Lawrence, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 124-125 and 233.) (94/35 U.S.A.)

The N.A.C.A are building an 8½ million dollar research laboratory solely for engine research. Up to the present, most of the engine research in the U.S.A. has been carried out by the larger engine firms themselves, and whilst this led to the production of civil aviation engines second to none, the military side has been neglected. High speed at high altitude is very expensive, yet of paramount importance in war. The concensus of military opinion favour the water-cooled engines of small frontal area for this purpose. Engines of this type have only been developed comparatively recently in the U.S.A. and they lack as yet the horse-power of the more perfected air-cooled radials on which most of the money has been spent. The research funds set aside by the U.S.A. Government for such problems as the aircraft diesel, safety fuel, etc. were too small to ensure rapid progress. Thus the two-cycle diesel has been under investigation for over ten years at Langley Field. If the facilities had been sufficient so that all that was accomplished could have been completed in three years instead of ten, every one would have regarded the results as remarkable. In the words of the author: "If a project, either through lack of funds, lack of talent, or both, does not move fast enough, it does not move at all, for to fall behind in the procession is to accomplish nothing."

Apart from liquid-cooled engine development, the author lists the following problems as worthy of the attention of the new laboratory:—

(1) High pressure superchargers of the rotary type not requiring intercoolers.
(2) Exhaust-driven superchargers.
(According to the author, although superchargers are at present in production, they are not yet a proved article.)
(3) Safety fuels and fuel injection.
(4) Two-cycle aircraft engine, either compression or spark-ignition, fitted with exhaust-driven scavenge blower and gear-driven supercharger, B.M.E.P., of the order of 250 lb. per sq. in.
(According to the author, it should be possible to obtain about 4,500 h.p. from an engine of the size and weight of the D.B.601.)

On the Rate of Reaction in the System Mineral Oil Oxygen. (D. J. W. Krenlin and J. ter Horst, J. Inst. of Petroleum, Vol. 27, No. 213, July, 1941, pp. 275-292.) (94/36 Great Britain.)

The author employs the method of Luther and Plotinkow, both the liquid and gas phase being present during the reaction in a closed vessel. A constant pressure of oxygen is maintained (5 cn. Hg.), the gas being constantly stirred into the liquid (medicinal paraffin oil) maintained at a constant temperature of 100°C. The dielectric strength of the oil is measured by the high-frequency method and from this the average dipol moment is estimated at regular intervals. The reaction velocity is then proportional to the rate of change of dipol moment, provided the solution velocity of the oxygen is large compared with reaction velocity. It was found that after an induction period of about 35 hours, the average dipol moment increased linearly with time, showing that the subsequent reaction velocity was constant ($K \approx 1.3$) up to dipol moment of the order of $\mu = 7.5 \times 10^{-18}$ e.s.u.

If the oxidation is carried out in the presence of metallic copper or tin, the rate of reaction is unchanged but the induction period shortened considerably. The authors conclude that the metal exerts no catalytic effect but acts entirely by absorbing anti-oxygen compounds present in the oil. The first addition of the metal thus exerts the greatest effect and after passing the induction period, the metal is apparently completely inert. The authors consider that the reaction velocity and length of induction period are important oil characteristics which can be measured conveniently by the electrical method. Purely chemical (acid content) or physical methods (viscosity) are apt to give misleading results as regards oil stability.

The Blending Octane Numbers of Furan and Furfuryl Alcohol. (H. B. Nisbet, J. Inst. of Petrol., Vol. 27, No. 213, July, 1941, pp. 293-300.) (94/37 Great Britain.)

From the information which has been made available recently regarding the blending octane numbers of hydrocarbons and other compounds it has become apparent that this property is improved when (1) the molecule of an aliphatic hydrocarbon is highly centralized, (2) in addition to centralization in the open-chain hydrocarbon molecule there are also present one or more unsaturated linkages, (3) cyclic hydrocarbons contain unsaturated linkages and when the nature of the cyclic hydrocarbon becomes fully aromatic. It is also known that certain alcohols, particularly the lower aliphatic compounds, and also some ethers—*e.g.* isopropyl ether—possess high-blending octane numbers.

In the present investigation the effect of combining a ring structure containing conjugated double bonds with an ether linkage as found in the molecule of furan and the combination of this structure with an alcoholic group, as in furfuryl alcohol, on the octane blending number has been studied from various angles.

Furan.—Furan was added in various concentrations to motor spirit blends of different octane numbers, and it was found that in blends of low octane number the addition of small proportions of furan caused a big rise in octane number. This relative rise decreased with increasing proportions of furan, until when 30 per cent. was reached the rise became negligible.

The addition of furan to blends of high octane number caused only a slight increase in octane number, and when added to commercial iso-octane, a decrease in octane number was observed.

Furfuryl Alcohol.—Owing to the insolubility of furfuryl alcohol in motor spirit of an aliphatic nature, the investigation was limited to the comparison of the blending values of furfuryl and ethyl alcohols in 10 per cent. blends in spirit containing benzole. The blending octane number of furfuryl alcohol in these blends are not as high as those of ethyl alcohol.

The Viscosity of Russian and Rumanian Lubricating Oils at High Pressure. (R. B. Dow, J. S. McCartney and C. B. Fink, J. Inst. of Petroleum, Vol. 27, No. 213, July, 1941, pp. 301-309.) (94/38 Great Britain.)

The oils examined (four Russian and three Rumanian) were typical products of the respective sources of origin. The viscosities were measured over the pressure range 0-46,000 lb. per sq. in. with the Hersey Rolling Ball Viscometer at temperature of 100°F., 130°F. and 210°F. respectively. For a pressure rise of 14,000 lbs. per sq. in. the viscosity increases between ten and twenty times at 100°F. and between five and ten times at 210°F. The results at any given temperature can be represented by an equation of the type

$$\mu_p = \mu_o^{a\rho} \times C$$

where μ_p = viscosity at pressure p.
μ_o = viscosity at atmospheric pressure.
ρ = density of oil at p.
a and C are constants.

From a comparison of similar experiments carried out on Pennsylvanian oil, it appears that the pressure effect on the viscosity of the Russian and Rumanian oils is considerably greater than in the case of typical paraffinic oils.

On a Relation Between Viscosity and Density of Liquids and Liquid Mixture. (M. K. Srinivasan, Phil. Mag., Vol. 32, No. 212, September, 1941, pp. 253-258.) (94/39 Great Britain.)

(1) An equation of the type $\log \eta = a + \beta(\rho_o - \rho)$ (where η is viscosity, ρ density, and a, β and ρ_o are constants) is proposed and is shown to represent the variation of viscosity of unassociated and associated, organic and inorganic liquids, with temperature.

(2) The same equation represents the viscosity variation with temperature of binary liquid mixtures at constant composition.

(3) It also represents at constant temperature the viscosity variation of ideal binary liquid mixtures with composition.

Lecithin as Stabiliser for Leaded Fuels. (Autom. Ind., Vol. 85, No. 4, 15/9/41, p. 25.) (94/40 U.S.A.)

Lecithin produced from Soya beans is said to have proved of value as a stabilizer for petrol, and especially leaded petrol. When leaded petrol is exposed to sunlight it may become cloudy, colour changes may take place, and the fuel tank may be subjected to corrosion in the presence of moisture. In one particular case the addition of 10 lb. of soyabean lecithin to 1,000 barrels of aviation gasoline is said to have prevented the formation of precipitates. The corrosion-inhibiting properties of lecithin are especially valuable in the case of aircraft, which usually have fuel tanks made of sheet aluminium.

The Behaviour of Lubricating Oils at Low Temperatures. (K. Siebald, Luftwissen, Vol. 8, No. 7, July, 1941, pp. 224-228.) (94/42 Germany.)

Investigations on the low temperature properties of complex mixture such as lubricating oils concern mainly their resistance to flow, both as regards the initiation of motion and the maintenance of the subsequent flow.

The low temperature starting resistance can be estimated in a special apparatus developed by the I. G. Farben, which records the force required to move a piston previously stuck by the cold oil crystallite. Viscosity determination at low temperature (*i.e.* actual flow) carried out by the usual methods are rendered inconsistent by the phenomena of plasticity exhibited by oils under these conditions. These difficulties have been overcome by the D.V.L. by carrying out the viscosity determination under pressure of the same order as occur in the engine circuit.

Under these high pressures the oil crystals are broken up and consistent pseudo laminar flow is obtained. It is stated that by the use of the I.G. and D.V.L. instruments an accurate laboratory rating of the oils as regards their low temperature behaviour in an engine has been possible for the first time.

Electrolytic Hexane. (Autom. Ind., Vol. 85, No. 4, 15/9/41, p. 62.) (94/41 U.S.A.)

German investigations have shown that hexane, one of the principal constituents of petrol, can be obtained by electrolysing butyric acid, which is produced by fermentation. By subjecting butyric acid to thermal decomposition, di-n-propyl ketone is obtained, a compound having a freezing point of minus 29 deg. Fahr. and a boiling point of 289 deg. The octane number of this product ranges between 92 and 99. It will mix readily with either absolute or hydrated alcohol and in this form can be used as motor fuel.

Corrosion Resistance of Free-Machining Stainless Steel. (S. P. Watkins, Met. Prog., June, 1941, pp. 710-714.) (94/43 Great Britain.)

Whilst resistant to many corrosive media stainless steels may be affected by minute changes in exposure conditions or minor changes in metal composition. The addition of sulphur or selenium for free-machining properties for instance, reduces the corrosion resistance of stainless steels, especially under severe conditions. Results of comparative tests of the effects of acetic, hydrochloric, nitric and sulphuric acids, salt spray and tap water on free-machining and regular grades of stainless steel are tabulated. In general, hydrochloric and sulphuric acids and salt spray affect most grades, whilst free-machining grades are unsatisfactory with boiling concentrated solutions of nitric acid.

(Abstract supplied by Research Dept., Met. Vick.)

Non-Ferrous Physical Metallurgy. (R. M. Brick and A. Phillips, Metal Industry, 18/7/41, pp. 42-44.) (94/44 Great Britain.)

The present status of metallurgical thought on plastic deformation, strain hardening and re-crystallization is reviewed by the authors. Coppergas reactions are also discussed noting that recent investigations on the copper-oxygen system have been conspicuously successful in that many of the results are of immediate practical value. The question of internal oxidation in copper-base alloys is considered followed by an outline of recent work on fatigue. Finally the authors deal briefly with important developments in regard to the magnesium industry.

(Abstract supplied by Research Dept., Met. Vick.)

Weldability—Base Metal Cracks. (Spraragen, Claussen, Weld. J., 1941, pp. 201-219.) (94/45 Great Britain.)

This review deals with cracks which started in the base metal before the welded part was placed in service. The various aspects of the problem are dealt with in considerable detail and a bibliography of 147 references is appended.

(Abstract supplied by Research Dept., Met. Vick.)

Friction and Surface Finish (M.I.T. Symposium). (Various authors, Metal Industry, Vol. 59, No. 5, 1/8/41, p. 69.) (94/46 Great Britain.)

Almost any of the current methods of finishing moving internal-combustion engine parts as *e.g.* by turning, grinding or honing, results in the formation of a layer of excessively distorted metal, which is undesirable, since in " running-in " operations it leads to accelerated wear. A process for removing this layer of fragmented or " smear " metal has therefore been perfected which is known as " super-finishing."

The basic differences between super-finishing and other forms of abrasive finish are that the speeds of finishing are 3-50 ft./min. for the former, while

6,000-10,000 ft./min. is normal for grinding, and the corresponding pressures are 1-30 lb./in.^{2} as against 500-1,000 lb./in.^{2} for honing; it is evident that the high abrasive pressures and speed of honing and grinding cause local heating which develops defective fragmentary crystal surfaces. Super-finishing involves random motion of a vibratory order with strokes of 1/16 in. to 1/4 in. at 300-3,000 reversals/min., and light oil of the proper viscosity carries away the abraded particles. The process is obviously not a dimensional operation in the machine tool sense, but is essentially a finishing operation only, whereby the "smear" metal is removed.

Generators for Producing Gases of a Given Composition for Heat Treatment Furnace "Atmospheres." (E. E. Slowter and B. W. Gonser, Metal Industry, Vol. 59, No. 5, 1/8/41, pp. 71-75.) (94/47 Great Britain.)

The recent trend in the development of new equipment for the production of controlled atmospheres has been directed to the making of atmospheres which are as nearly as possible in equilibrium with the material to be protected. For high temperature heating of medium and high carbon steels this has usually meant the elimination of CO_2 as well as H_2O, either by avoiding their production or by removing them after formation. Removal after forming may be by wet methods—that is, scrubbing the gas through mono-ethanolamine or other CO_2 absorbent—or by dry means such as passing over hot carbon.

The fact that much steel is still hardened in a partly or completely burned gas atmosphere is not due to ignorance on the part of the heat treater. He is usually well aware of the advantages of an atmosphere free of O_2, CO_2, and H_2O (and which will not deposit carbon) but all too frequently the conditions of operation and scope of his work do not warrant expensive controlled-atmosphere equipment. Attempts to protect the work mechanically by a copper paint, non-metallic coatings or similar means have been reasonably successful only under special conditions. Although effective protective coatings would be greatly welcomed, most steel heat-treaters are willing to make a moderate investment in controlled-atmosphere equipment and are watching with great interest the new types of simple and relatively inexpensive atmosphere producers. Some of them are described by the author.

Surface Hardening by Induction. (Mechanical Engineer, Vol. 63, No. 8, Aug., 1941, pp. 602-603.) (94/48 U.S.A.)

The heating is accomplished by the use of high-frequency currents. Specifically chosen frequencies from 2,000 to 10,000 cycles per sec. and upward of 100,000 cycles are being used extensively at the present time. Current of this nature, when caused to flow through an inductor, will produce a high-frequency magnetic field within the region of the inductor. When a magnetic material such as steel is placed within this field there is a dissipation of energy in the steel both due to hysteresis and eddy currents. Due to the well known skin effect, the heating is limited to the outside layers.

When the temperature of an inductively-heated steel bar arrives at the critical, all heating due to hysteresis ceases and that due to eddy currents continues at a greatly reduced rate. Since the entire action goes on in the surface layers, only that portion is affected. The original core properties are maintained and the surface hardening is accomplished by quenching when complete carbide solution has been attained in the surface areas. Continued application of power causes an increase in depth of hardening, for as each layer of steel is brought to temperature the current density shifts to the layer beneath, which offers a lower resistance. It will at once be obvious that the selection of the proper frequency and control of power and heating time will make possible the fulfilment of any desired specifications of surface hardening.

Induction hardening produces a hardness which is maintained through 80 per cent. of its depth, and from there on toward the core a gradual decrease through

a transition zone to the original hardness of the steel as found in the core which has not been affected. The bond is thus ideal, eliminating any chance of cracking.

In addition to the selective surface hardening of steels there have been other applications of induction heating of rather a unique nature. Hardening a piece of steel and brazing to copper and other metals may be done simultaneously. A small section of a previously hardened object can be drawn or softened to a condition possessing ready machinability. Heating for forging and upsetting has been found to be a particularly satisfactory use for induction heating. The speed with which this may be accomplished has made it readily adaptable to the high production requirements of forming equipment, and scale problems are reduced to a minimum. The corresponding increase in die life is of extreme importance. Tip annealing of brass cartridge shells at the rate 100,000 per hour is provided with a single induction-heating unit.

Friction and Surface Finish (M.I.T. Symposium). (Various authors, Metal Industry, Vol. 59, No. 6, 8/8/41, p. 89.) (94/49 Great Britain.)

The mechanism of wear is discussed and classified under the following headings: Cutting due to rough surfaces; abrasion by hard particles; corrosion by chemically active materials in the environment; galling due to molecular forces between metals as modified by surface films; and finally, pitting caused by the fatigue cracking of promontories on the surface, and the belief is expressed that all of these types of wear, except that of cutting wear, are important in service.

In the discussion which followed reference was made to the use of extreme pressure lubricants for " running in " operations, since these have a residual beneficial effect in reducing the wear of the metal parts, even when the lubricant is only plain mineral oil. References were also made to galling between mating surfaces, the formation of cocoa or fretting corrosion, and the actual welding of parts in service.

Fatigue Tests of Welded Joints (University of Illinois). (W. M. Wilson and others, Nature, Vol. 148, No. 3,748, 30/8/41, pp. 261-262.) (94/50 Great Britain.)

The primary object of this Progress Report by the Engineering Department of the University of Illinois was to obtain reliable information on which to base specifications governing the design of welded structural members subjected to reversed or pulsating stresses. The lack of knowledge of the fatigue strength of welded joints has been the principal deterrent to their adoption in the fabrication of bridges, and it was clear that tests on the largest practicable scale would have to be made before this method of construction could be placed on a satisfactory and reliable basis.

Three kinds of stress cycle were used: (1) from a tensile stress to an equal compressive stress; (2) from zero stress to a maximum tensile stress; (3) from a maximum tensile stress to a minimum tensile stress of half the value. These gave ratios r, of -1, 0 and $+0{\cdot}5$ respectively, and for each value of r, seven identical specimens were tested; three so as to fail at 100,000 cycles, and three at 2,000,000 cycles, the seventh being a spare to be tested as desired after the other six tests had been completed.

It appears that the dependable strength of welded joints and plates weakened by transverse welds is quite moderate. But welds in $\frac{7}{8}$ in. carbon-steel plates in the as-welded condition failed after two million cycles, for maximum stresses of 14,400, 22,500, and 36,900 lb. per sq. in. in the three classes of cycles. The corresponding figures for machined-off specimens of classes two and three were 28,400 and 43,700 and for ground-off specimens of class two were 26,300. Stress-relief did not appear to affect fatigue strength and periods of rest showed no advantage. Carbon-steel plates with one transverse fillet weld gave an

average of 18,900 and with two welds 13,000 lbs. per sq. in. The character of the bead had some effect on the figures, but for a given base metal the variation did not exceed five per cent.

A New Plastic Material. (Inter. Avia., No. 770/71, 27/6/41, p. 17.) (94/51 U.S.A.)

A construction material which apparently is particularly suitable for the aircraft industry has been developed under the designation *Fybr-Tech*. It consists of a single layer of wood with a layer of artificial fibre bonded by means of artificial resin to each side. The strength of this very light material is stated to be exceedingly satisfactory. Fybr-Tech can readily be sawn, drilled and stamped, immaterial of the direction of the grain, and can be formed under the application of heat without detrimental effect on the surface. Its resistance to meteorological influences is stated to be very good. The idea of using several laminated materials in the construction of aeroplanes is not new and has been adopted in France some considerable time ago. For example, the well-known "Plymax" skin, consisting of three-ply wood on which aluminium sheet was bonded by means of casein for the absorption of torsional stresses, was extensively used in the construction of the Morane 406 single-seater fighter.

A Thermodynamical Theory of the Tensile Strength of Isotropic Bodies. (R. Furth, Procs. Roy. Soc., Vol. 177, No. 969, 10/1/41, pp. 217-227.) (94/52 Great Britain.)

It is well known that attempts to calculate the tensile strength of crystals by means of the lattice theory have failed as yet: the tensile strength, calculated in this way, is about one hundred times larger than the actual value of this quantity, determined by experiments.

The lack of success of the former attempts to calculate the tensile strength from a pure atomistic theory has long ago led many physicists to believe that the usual experiments do not give the real values of the tensile strength because of the imperfections of the real crystals, such as small holes and cracks, which could considerably diminish their strength. Several attempts have been made to perform the experiments under such conditions as to compensate for these defects. But the results of these experiments are not very convincing, and the whole conception of the "apparent" and the "real" strength is very unsatisfactory and improbable.

In a recent paper M. Born (1939) has developed a theory of the melting of crystals based upon principles very similar to those which are used for the treatment of the breaking of crystals mentioned above.

The results of this theory are, however, in good agreement with the experimental facts as regards the absolute value of the melting temperature and its dependence on the pressure.

According to Born's theory melting is nothing else than a breaking due to the action of the heat movement of the atoms; or putting it the other way round, breaking is nothing else than melting enforced by the action of the external forces. So it might further be suggested that the tensile strength should rather be connected with the heat of melting than the heat of sublimation per unit of volume, as predicted by the lattice theory.

This fact was the starting point for the author's considerations which have led to a formula relating the tensile strength of an isotropic body with the heat of melting per unit of volume, in good agreement with the experiments.

Alternative Materials and Design. (G. F. Titterton, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 148 and 241.) (94/53 U.S.A.)

The author presents a number of suggestions for easing the current situation in the American Aircraft Industry, in which the best material for a given job is frequently not available.

AL. ALLOY.—Substitution of common alloy for the heat-treated variety requires the use of a heavier gauge and the insertion of alclad washers below the rivet heads. Extruded shapes may be replaced by fabricated sections. Formed shapes invariably entail an increase in bend radius and the consequent change in rivet position (to obtain a flat seat) requires careful consideration.

The possibility of obtaining the required extrusion from re-working one in stock must therefore not be lost sight of.

STEELS.—The difficulty of obtaining standard S.A.E. 2330 Nickel Steel commonly used for aircraft bolts has necessitated the use of chrome molydenum and modification of the bolt manufacturing equipment, unless the bolts are turned on a lathe.

Forgings of S.A.E. 4140 of electric furnace aircraft quality are also difficult to obtain. It is stated that open hearth steels to government specification can be substituted, provided a proper X-Ray or Magnaflux inspection is carried out. For the early planes of a production order the use of smith or hand forgings is recommended. The stocks of Cr. Mo. steel (almost exclusively used up to now in aircraft construction) can be conserved by restricting its present use to highly stressed parts and using mild carbon steel (S.A.E. 1020 or 1025) whenever possible.

The alternatives proposed do not necessitate any marked changes in design and for this reason plastics and plywood are not included. When the development of these materials is further advanced the metal procurement problem should be eased considerably, since complete sub-assemblies made of these materials should then become available.

Spot Weldability of Al. Alloys. (C. L. Hibert, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 190-200.) (94/54 U.S.A.)

Conditions which are known to affect spot weldability of Al. Alloys are: chemical composition, surface condition, conditions under which welding is performed, type of service to which the product is put and the technical education and experience of the welding personnel. The main difficulty is the high thermal conductivity of Al. Alloys which, however, depends to some extent on composition and heat treatment. Soft material is generally more conducting and correspondingly more difficult to weld. Conditions under which welding takes place, such as machine settings, size and shape of electrodes, edge distance and accessibility play a large part on the success or failure of the operation. The author discusses some of these points in detail and describes modern form of equipment designed to rule out the personal element as much as possible. Of all the factors, the human element is the most difficult to control. Each operator has his own method and at least six months are required to train him to the point where consistent work can be expected. Quality, rather than speed, is to be aimed at.

At present most of the spot welding is restricted to secondary structures. A proper weld is, however, as strong as the rivetted job. The difficulty is to ensure consistency in large scale production and devise a method of non-destructive testing.

Internally Heated Electric Salt Bath. (Aero Digest, Vol. 31, No. 1, July, 1941, p. 214.) (94/55 U.S.A.)

Based on a design which is described as the "electrothermic-permeation" principle, an improved type of internally heated electric salt bath furnace is reported, capable of producing more uniform heat, reducing fuel costs, and eliminating excessive spoilage of carburizing salts; it also features a ceramic pot which can be guaranteed for at least one year's operation.

Range of operation available with the furnaces includes virtually any heating operation requiring temperatures of from 300° to 2,500°F. and the "proving"

period for the furnaces is said to have covered almost every classification of temperature, composition and size of work. Furnaces are now available for carburizing, cyaniding, hardening of molybdenum and tungsten high-speed steels, selective hardening, brazing, heating for forging, treating aluminium alloys, tool tipping, etc. in a range of sizes suitable for either batch or continuous operation.

Advantages claimed for the new design are: greater efficiency due to generation and distribution of heating throughout entire pot with larger percentage of heat developed at the bottom; elimination of super-heated spots to destroy chemical balance of bath; spacing of electrodes to prevent possibility of shorting and burning the work; 20 per cent. greater working area.

The electrothermic-permeation principle takes its name from the fact that the heat for the bath is generated throughout the effective confined separate heating area. Distribution of current flow for working space rather than in a heating, the salt is by a unique arrangement of electrodes so that the greatest heat is at the bottom of the pot, with the balance decreasing in intensity as it approaches the surface of the liquid.

X-Ray Analysis in Industry. (J. Sc. Inst., July, 1941, pp. 126-158.) (94/56 Great Britain.)

The second part of this Symposium is reproduced in this issue and is devoted to the technique of X-Ray analysis methods and some recent developments. Thirteen papers are recorded and include the following:—Photometry of X-Ray Crystal Diffraction Diagrams; a simple photometer for the examination of X-Ray films; experimental technique in the study of alloy by X-Rays; X-Ray crystal photography at low temperatures; measurement of stress by X-Rays; some applications of X-Ray methods in the examination of organic crystals; the derivations of lattice spacings from Debye-Scherrer photographs; systematic determination of crystal orientation; some applications of X-Ray technique to the study of preferred orientation of crystals in metals; Supperlattices; X-Ray diffraction and the deformation of metals; precipitation in the solid state and particle size measurement by the X-Ray method.

(Abstract supplied by Research Dept., Met. Vickers.)

Instrument Bearings. (Mechanical Engineer, Vol. 63, No. 8, Aug., 1941, pp. 601-602.) (94/57 U.S.A.)

Diamonds, rubies, sapphires, synthetic sapphires, garnets, chrysoberyl, spinels, zircons, topazes, rock crystal, and agates, are made into watch and chronometer jewels and bearings for meters and other scientific instruments.

The diamond, although superior to other gems, is not widely used due to the cost of the rough stone and the time and labour expended in shaping this, the hardest of all substances.

Sapphire and ruby jewels (mostly synthetic) serve as pivots and counter-pivots. Such jewels are not pierced but are cut into "cup jewels." Jewelled bearings are also used for bomb fuses and in the instruments for combat aeroplanes and bombers. A modern Curtiss pursuit plane has at least ninety instruments, dials, knobs, etc., and many of these require jewel bearings. Navigation watches alone have 21-jewel movements.

Quartz Membrane Manometers of Small Volume. (Kenty, Rev. Sci. Instrum., Nov., 1940, pp. 377-386.) (94/58 Great Britain.)

Fused quartz membrane manometers, used as null instruments, have been developed for measuring the pressures of vapours or gases from a few centimeters of mercury to 50 atmospheres, with an accuracy of the order of 0.1 per cent. It is stated that all-quartz manometers are remarkably constant in calibration,

are operable at temperatures of 800°C. or higher, and are extremely rugged and free from explosion hazard at high pressure.

(Abstract supplied by Research Dept., Met. Vickers.)

An Omni-directional Radio Range System. (D. G. C. Luck, R.C.A. Review, Vol. 6, No. 1, July, 1941, pp. 55-58.) (94/59 U.S.A.)

Radio navigation may be done with direction-finding receivers on mobile craft, with fixed direction-finders on the ground or with directional beacon transmitters on the ground. Each method has its unique merits and faults, but the last seems especially suited for aircraft guidance in the United States and has, in the form of four-course radio "range" beacons, rendered outstanding service. The disadvantages of limited choice of courses and of difficulty in definitely determining on which course a craft may be, inherent in the present four-course ranges, may be avoided by rotating a transmitted radio beam and timing its passage over the receiving craft to determine uniquely the bearing of that craft from the known location of the beacon transmitter.

A rotating beam, of figure-eight shape, may be produced without mechanical motion by setting up two fixed antenna systems having figure-eight directivity at right angles and feeding them with radio-frequency signals modulated at the desired rotation frequency, the modulation of the separate supplies to the two crossed antennas being in phase quadrature. Unmodulated carrier to resolve the ambiguity of the figure-eight beam, by changing its shape to a limaçon, is radiated from a non-directive antenna, and a timing reference is provided by interrupting all transmission momentarily just as the beam points north.

The audio output from a receiver tuned to this beacon comprises a sine wave produced by the sweep of the beam and a train of impulses produced by the reference keying. The sine component is filtered, split in phase and used to drive a cathode-ray beam in a circle, in step with the rotation of the transmitted beam. The impulses are used to slow up the beam electrons momentarily, marking the swept circle with an outward jog, and so indicating receiver bearing directly. The impulses also actuate a zero-centre meter, while the sine wave renders this meter insensitive at a certain moment of the cycle and oppositely sensitive just before and just after that moment. By adjusting the sine wave phase, the meter may be centred when the receiver is on any desired bearing, and thereafter will indicate any departure from that bearing. A special broadcast transmission may be used to check adjustments of receiving indicators.

Certain conditions as to modulation phases and amplitudes, antenna-current phases and amplitudes, antenna geometry and cathode-ray indicator voltage phases, amplitude and tube geometry must be fulfilled if accurate bearings are to be obtained. Study of these conditions shows all adjustment tolerances to be of reasonable magnitude, though considerable care in antenna construction is necessary to insure adequate symmetry of antenna-current phase.

On Starting an Electric Spark by Intense Ionisation of the Sparking Space. (T. Shimiza and M. Hirata, Scientific Papers of the Inst. of Phys. and Chem. Research, Tokyo, Vol. 38, No. 1,022.) (94/60 Japan.)

The sparking potential between spherical electrodes in air is somewhat variable and if such gaps are used for high-speed cinema exposures the fluctuation in the actual time of passage of the spark may introduce errors. In the author's arrangement of the gap, one of the sparking electrodes is hollow and provided with a thin metal foil window facing the second electrode. The hollow electrode forms part of a high vacuum grid type cathode-ray generator (triode) which ionises the gap and lowers its critical potential by about 30 per cent. The spark will now start with a time lag of less than 10^{-7}.

The new device will function either as:—

(1) An electric relay releasing considerable amount of energy almost instantaneously under very feeble stimulation,

(2) An arrangement for taking instantaneous photograph which is easy to control,

(3) A chonograph for measuring short time intervals with an accuracy of 10^{-7} sec.

The Effect of Rain and Fog on the Propagation of Very Short Radio Waves. (J. A. Stratton, Proc. I.R.E., Vol. 18, No. 6, June, 1930, pp. 1,064-1,074.) (94/61 U.S.A.)

The purpose of this paper is to investigate theoretically the effect of rain, fog, or clouds on the propagation of short radio waves. The theory of the propagation of electro-magnetic waves in a medium in which are suspended spherical particles of an arbitrary material is first reviewed. The available physical data on fog and rain is then referred to. The conclusions arrived at are that rain and fog have no effect on the propagation of radio waves of the frequencies now employed. Rain first begins to influence markedly the propagation of waves less than 5 cm. in length. Thereafter, the absorption increases very rapidly with decreasing wavelength, due both to scattering and the selective absorption of the water molecule. Infra-red radiation should not, therefore, prove satisfactory for communication purposes through heavy fog. The absorption coefficient for this case may be readily obtained from the formulas. For fog the formulas given in this paper are valid for wavelengths exceeding about 0.05 mm., provided the complex form of the index of refraction is used.

The CAA-MIT Microwave Instrument Landing System. (E. L. Bowles, W. L. Barrow and others, A.I.E.E. Trans., Vol. 59, 1940, pp. 859-864.) (94/62 U.S.A.)

This paper deals with the problem of developing an instrument landing system in which the pilot is kept informed as to both his location and orientation by the indications of a single instrument. The solution of this problem includes the application of centimetre waves, the development of a straight-line glide path, and the realization of a novel instrument combination. The apparatus was designed to demonstrate feasibility only. Commercial embodiment of the results is now within the reach of industry. In the course of the solution of the problem a landing system has been evolved embodying both a unique indicating instrument and landing path. The two elements, although used in combination in the system described, can also be applied independently. For example, the instrument may be used with constant intensity glide path and the straight-line glide path may be used with a conventional crossed pointer instrument. The landing path described in this paper marks a significant advance not simply because it is straight, and of an equi-signal nature, but because it demonstrates a means by which a path essentially free from the effects of ground and surrounding objects may be realized. The radio beam being thus substantially free from the effects of its surroundings makes the landing path reproducible and therefore makes the system truly portable. Although the 50-centimetre landing system was evolved it was felt that a 10-centimetre system would certainly be evolved in the near future.

Theoretical and Experimental Investigations of Electron Motions in Alternating Fields with the Aid of Ballistic Models. (H. C. Hollmann, Procs. of the I.R.E., Vol. 29, No. 2, Feb., 1941, p. 70.) (94/63 U.S.A.)

The motion of electrons and the exchange of energy in ultra-high-frequency transverse and longitudinal field is investigated theoretically and experimentally

by means of ballistic models in which single balls or a beam of balls roll over potential slopes whose gradients change with time. In this way there are represented by models, first a cathode-ray tube, then the Heil two-field generator, and finally the Klystron.

Heretofore, such tube models have only been employed for illustrating and investigating stationary phenomena. The rubber membrane is stretched over stationary supports and its form remains unaltered while the balls roll. However, dynamic phenomena can also be imitated in this manner. For this purpose the height adjustments of the membrane must be periodically altered and in a rhythm whose period is comparable with the transit time of the balls. Fundamentally it is immaterial in which direction the balls roll over such a dynamic membrane, that is to say, whether in the same direction, or normal to the direction of the field lines which are altering with time, consequently the model may provide for a transverse or a longitudinal control or for a resultant of the two components.

The actual purpose of the models and researches which have been discussed is not only to derive the efficiency functions from the mechanical premises but especially to provide the exact insight into the excitation phenomena which is not so easy to obtain in the region of micro-waves with a 10^8 time refinement. Furthermore, by means of the ballistic model there can be obtained exact data for the suitable proportioning of the electrical apparatus initiated by the mechanical models.

Electro-Magnetic Horn Design. (L. J. Chu and W. L. Barrow, A.I.E.E. Trans., Vol. 58, July, 1939, pp. 333-338.) (94/64 U.S.A.)

The principles of designing electro-magnetic horn " antennas " to obtain beams of specified angular spread, smoothness of contour and power gain are disclosed. Although a wide variety of shapes is possible, a shape having a rectangular cross section perpendicular to the central axis of the horn is preferable because it is capable of producing a linearly polarized wave and also permits an independent control of the width of the radiated beam in the horizontal and vertical planes. Horns having straight sides in the longitudinal cross section have been most used because of the economy and ease of construction and because thorough analysis of this structure has been made. Quantitative curves are given from which the design of sectoral and pyramidal horns may be readily made. The material from which the horn is made may be any of the highly conducting metals. Galvanized iron sheeting and thin electrolytic copper foil cemented to plywood have both proved satisfactory. Screen or other semi-open construction may also be employed. Two general methods of exciting the horn are available: (1) the hollow-pipe feed, and (2) direct excitation.

Aircraft Radio, 1939. (Electronics, Jan., 1939, pp. 10-14, 43.) (94/65 U.S.A.)

A report of the technical background of recent developments of aircraft radio services. Recent achievements are reviewed in the use of radio for solving the problems of altimetering, course finding and course marking, blind landing and traffic control. One of them was the absolute altimeter developed jointly by United Airlines and the Bell Laboratories. Its significance lay in the use of the highest frequency yet applied to regular service, 500 Mc. Another was the development by the M.I.T. of a blind landing system, using " horn " radiators of the wave-guide type. A cathode-ray tube is used as indicator in this system. Yet another was the radio direction finder jointly announced by the Sperry Company and the R.C.A. Manufacturing Company operating on the 350-450 Kc. beacon band, which is completely automatic in operation, pointing toward the station being received without any attention from the pilot.

Theory of the Electro-magnetic Horn. (W. L. Barrow and L. J. Chu, Proc. I.R.E., Vol. 27, No. 1, Jan., 1939, pp. 51-64.) (94/66 U.S.A.)

This paper deals with the theory of the transmission of waves through the inside of the horn and into the outer free space. Although the analysis applies specifically to the sectoral horn, it provides a clear physical picture of the operation of electro-magnetic horns of any shape. The analysis applies directly to the transmission of waves in a hollow pipe-line with constants that change along its length, that is, to a " tapered " hollow-pipe line. The analysis also bears on the operation of a tapered section of hollow-pipe used as a connection between two uniform hollow-pipe lines of unequal cross sections. Such tapered sections may be used to reduce the electrical discontinuity when joining two pipes of unequal dimensions, for an aid in matching their impedances, and for other purposes. The analysis falls naturally into two parts. In the first part the boundary conditions for a horn of perfect conductivity and of infinite length is imposed on the appropriate solutions of Maxwell's equations to obtain the expressions for the electric and magnetic fields within the horn and to derive the more important transmission properties of these internal waves. In the second part Huygens' principle is invoked to calculate the shape of the radiation field at a great distance from the mouth of the horn by assuming the distribution across the mouth to be the same as would exist there if the sides of the horn extended to infinity. Certain transmission quantities, like the phase constant, attenuation constant, velocity of propagation, etc. are calculated for horns of any angle of flare and the field configuration within the horn is plotted. One result is a clear understanding of the propagation of waves within the horn. Another result is that design specifications for horns may be established. Calculations of radiation patterns made in this analysis agree satisfactorily with experiments reported in a companion paper.

Materials for Electrical Contacts. (J. C. Chaston, J. Inst. of Elect. Eng., Vol. 88, Pt. II, No. 4, Aug., 1941, pp. 216-301.) (94/67 Great Britain.)

The principal types of failure in light- and medium-duty electrical contacts are analysed in detail and an account is given of the characteristics of the commonly used contact materials.

The effects on contact resistance of the size, shape, surface finish and closing pressure of light-duty contacts are discussed; an account is given of the resistance of contact materials to the formation of tarnish films; and attention is directed to the effects of dust and grease films in causing failure.

In medium-duty contacts, when arching occurs, the most serious cause of failure is the action known as " material transfer " which takes place when direct currents are interrupted. As a result of transfer the contact gap may close and the contacts finally interlock. The factors which influence material transfer are discussed, and curves are reproduced to show the limiting current and the rate of build-up for a number of common contact materials under given test conditions.

A second cause of failure is the welding together of the contacts by the current surge at make. The inherent tendency of a number of contact materials to weld together has been measured.

In sliding contacts excessive wear is a frequent cause of troubles. A method of testing the wear of unlubricated surfaces is described, and the results of measurements on a number of combinations are tabulated.

Making Greater Use of Invention. (S. MacDonald, Engineer, Vol. 172, No. 4,468, 29/8/41, pp. 135-137.) (94/68 Great Britain.)

If an examiner has a definite dislike of some part of an invention he should be allowed to say that he belongs to another school of thought, and advise that the matter should be handed to someone else for consideration. In view of

this natural attitude, the people to whom the report is made should not depend on the report of one man or even one group of men working together, unless minority statements are permitted.

This country gained its colonies and foreign connections through the venturesome spirit of its sailors; and it got its export trade through having the technicians, the factories, the raw materials, the internal and external transport facilities, and the financial power which other nations lacked, and it sold wealth-producing instruments, such as railways, on the hire-purchase system (foreign loans). It has lost that position, and the only way to hold at least some of the foreign trade seems to be for the manufacturers and customers here to display more of the venturesome spirit and take risks.

Inventions must be developed by ourselves. We can no longer afford to wait till they are proved a commercial success.

Our Unused Potentialities for Aeronautical Research and Development. (J. E. Younger, Mechanical Engineer, Vol. 63, No. 8, August, 1941, pp. 575-576.) (94/69 U.S.A.)

Funds have been provided for practically every phase of aviation except the most important phase of all, *i.e.* the training of engineers whose business it will be to design and superintend the construction of those marvels of mechanism, the aeroplanes of the future, and to make those aeroplanes better than they can be made anywhere else in the world.

If additional educational training for the aeronautical engineers who are to be the designers of the future air liners is to be provided for, and certainly this will be absolutely necessary, additional funds must come from some other source, *i.e.* personal endowment, endowment by the industry, or endowment by the National Government.

Other aeronautical sciences are so far behind the science of aerodynamics in development that practical use cannot be made of the new discoveries in aerodynamics. By all means the development of aerodynamics must not be slowed down, but other phases of the aeronautical sciences of equal importance should be given equal consideration for a balanced programme. The standard of aeronautical training and research in structures, materials, fabrications, and other phases of aeronautics must be brought up at least to the standard set for aerodynamics.

Electrical Machine Solves Heat Transfer Problems. (Swain Power, July, 1941, pp. 76-78.) (94/70 Great Britain.)

Details are given of a method of solving complicated heat-transfer problems by converting the thermal constants and variables to analogous electrical units. The machine described has fifteen sections and can be used to duplicate any heat-transfer structure that can be suitably represented by fifteen divisions.

(Abstract supplied by Research Dept., Met. Vickers.)

LIST OF SELECTED TRANSLATIONS.

No. 37.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft Production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

WARFARE.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND REFERENCE.
1255	Shaurov, N. ...	*The Use of Armour in Aircraft.* (Air Fleet News, U.S.S.R., Vol. 25, No. 3, March, 1941, pp. 243-247.)
1271	Yassin, E. Z. ...	*The Use of "Dummies" in the Camouflage of Operational Aerodromes.* (Air Fleet News, U.S.S.R., Vol. 25, No. 5, May, 1941, pp. 432-439.)

AERO-HYDRODYNAMICS.

1263	Flugge-Lotz, I. ... ... Ginzel, I	*Two-Dimensional Flow Round a Slotted Flap.* (Ing. Archiv., Vol. 11, No. 4, Aug., 1940, pp. 268-292.)
1245	Riegels, F. ... ... Weber, J.	*Contribution to the Design of Impellers Subjected to Shock at Entry.* (Ing. Arch., Vol. 12, No. 1, Feb., 1941, pp. 63-69.)

AIRCRAFT AND ACCESSORIES.

1247	Kronauer, E. von ...	*Dynamic Balance of Airscrews.* (Flugwehr und Technik, No. 6, June, 1941, pp. 141-144.)
1274	Horten, G.	*"Horten V" All-Wing Aircraft.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 118-119.)

MATERIALS.

1253	Wiederholt, W. ...	*Surface Protection of Metals.* (Z.V.D.I., Vol. 85, No. 20, 17/4/41, pp. 451-459.)
1273	Eisele, K.	*Pilot Balloons Made from Transparent Plastic Film.* (L.F.F., Vol. 18, No. 4, 22/4/41, pp. 147-154.)

ENGINES AND FUELS.

1242	Weltin, C.	*Double Test Stands for Aero Engines.* (Z.V.D.I., Vol. 83, No. 47, 25/11/39, pp. 1,237-1,238.)
1265	Volkov, G. K. ...	*Some Peculiarities in the Working of Aircraft Fuel Systems.* (Air Fleet News, U.S.S.R., Vol. 23, No. 5, May, 1941, pp. 442-444.)
1266	Fokin, M. P. ...	*Operation of Aircraft Fuel Systems at High Altitudes.* (Air Fleet News, U.S.S.R., Vol. 23, No. 5, May, 1941, pp. 445-447.)
1248	Vokhmyanin ...	*Petrol Poisoning in Flight.* (Air Fleet News, U.S.S.R., Vol. 23, No. 3, March, 1941, pp. 265-267.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING AUGUST, 1941, TOGETHER WITH LIST OF NEW TRANSLATIONS RENDERED AVAILABLE.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of the Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example that published by the Aeronautical Research Committee) is already known to these Staffs.

Theory and Practice of Warfare.

79/1	Germany ...	*The New German Mauser Cannons* (15 *mm. and* 20 *mm.*). (Aeroplane, Vol. 61, No. 1,575, Aug. 1st, 1941, p. 113.)
79/2	Great Britain	*Short Stirling Heavy Bomber* (*Photograph*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, pp. 112-113.)
79/3	U.S.A. ...	*Glen Martin* 187 *Baltimore* (*Photograph*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 115.)
79/4	U.S.A. ...	*Brewster Bermuda Two-Seat Dive Bomber* (*Drawing*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 115.)
79/5	U.S.A. ...	*Boeing Fortress I* (*Photograph*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 116.)
79/6	U.S.S.R. ...	*Russian Aircraft Photographs* (*I.* 187 *and S.B.* 2). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 117.)
79/7	Great Britain	*Douglas Havoc Night Fighter* (*Photograph*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 119.)
79/8	Germany ...	*Messerschmitt Me.* 109*F* (*Description of Captured Aircraft*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, pp. 120-122.)
79/9	Germany ...	*German High Command of Air Operation in* 1941 *up to the Conquest of Crete*. (Aeroplane, Vol. 61, No. 1,575, 1/8/41, pp. 124-125.)
79/10	U.S.A. ...	*Consolidated Liberator* (*Photograph*). (Aeroplane, Vol. 61, No. 1,575, 1/8/41, p. 133.)
79/11	Great Britain	*Uses of Wood in Warfare*. (Nature, Vol. 148, No. 3,745, 9/8/41, p. 161.)
79/12	U.S.A. ...	*Will Bacteria be Used in War* (*Insurmountable Difficulties Explained*). (J. J. Kershaw, Scientific American, Vol. 165, No. 2, Aug., 1941, pp. 56-58.)
79/13	U.S.A./ Great Britain	*Vultee "Vanguard* 48·*D.*" (Inter. Avia., No. 766, 27/5/41, p. 8.)
79/14	U.S.A. ...	*Vultee "Vengeance"* 72. (Inter. Avia., No. 766, 27/5/41, pp. 8-9.)
79/15	U.S.A. ...	*Douglas A.* 20*A Twin Engine Attack Bomber* (*Development of Boston DB-7*). (Inter. Avia., No. 766, 27/5/41, p. 9.)
79/16	U.S.A. ...	*Mass Production of Consolidated B-24 Heavy Bomber*. (Inter. Avia., No. 766, 27/5/41, p. 10.)
79/17	Great Britain	*Dinghies for British Fighters*. (Inter. Avia., No. 766, 27/5/41, p. 15.)

79/18 Great Britain *Luminescent Materials and Their War Time Use.* (Nature, Vol. 148, No. 3,743, 26/7/41, pp. 118-119.)

79/19 Germany ... *External Ballistics—Angle of Elevation and Range as Affected by Topographical Features (Elevation or Depression of Target with respect to the Horizontal).* (K. Stange, Z.G.S.S., Vol. 36, No. 6, June, 1941, pp. 115-120.)

79/20 Great Britain *Bristol Beaufighter.* (The Engineer, Vol. 172, No 4,465, 8/8/41, pp. 92-93.)

79/21 U.S.A. ... *Consolidated P.B. 27-2 Four-Engined Flying Boat Petrol Bomber.* (Scientific American, Vol. 165, No. 2, Aug., 1941, p. 94.)

79/22 U.S.A. ... *Aircraft Armour—Production Speed-Up.* (Scientific American, Vol. 165, No. 2, Aug., 1941, p. 95.) (Abstract available.)

79/23 Germany ... *Variation in Shell Trajectory by Change in One of the Principal External Characteristics (Ballistic Coefficients, Muzzle Velocity, Elevation, Air Density, Wind).* (H. Knobloch, Z.G.S.S., Vol. 36, No. 7, July, 1941, pp. 137-140.)

79/24 Germany ... *Parachutes and Their Manufacture.* (G. Sedlmayer, Luftwissen, Vol. 8, No. 5, May, 1941, pp. 146-150.) (Abstract available.)

79/25 U.S.A./Germany ... *Tail Units of Lockheed Hudson and Me.* 110. (Flight, Vol. 40, No. 1,708, 18/9/41, p. c.)

79/26 Great Britain *Short Stirling.* (Aeroplane, Vol. 61, No. 1,581, 12/9/41, p. 27.)

79/27 U.S.A. ... *Black-Out Lighting on Army Vehicles.* (Autom. Ind., Vol. 84, No. 11, 1/6/41, pp. 582-583.)

79/28 U.S.A. ... *Republic XP 47B Thunderbolt (Photograph).* (Autom. Ind., Vol. 84, No. 11, 1/6/41, p. 587.)

79/29 U.S.A. ... *Boeing Fortress I High Altitude Bomber.* (Flight, Vol. 40, No. 1,704, 21/8/41, p. 106.)

79/30 U.S.A. ... *Douglas B. 19 Giant Aircraft.* (Air Services, U.S., Vol. 26, No. 7, July, 1941, pp. 25-26 and 38.)

79/31 Great Britain *Bristol Beaufighter (Photograph).* (Airc. Eng., Vol. 13, No. 150, Aug., 1941, p. 210.)

79/32 Germany ... *Ha 139 Long Range Float Seaplane.* (Airc. Eng., Vol. 13, No. 150, Aug., 1941, pp. 218-220.)

79/33 Great Britain *Black-Out in Factories.* (Airc. Eng., Vol. 13, No. 150, Aug., 1941, pp. 225-226.)

79/34 Great Britain *Bristol Beaufighter.* (Engineering, Vol. 152, No. 3,943, 8/8/41, pp. 116-117.)

79/35 U.S.S.R. ... *Armour on Aircraft.* (B. Ivanov, Aeroplane, U.S.S.R., No. 3, March, 1941, pp. 36-37.)

79/36 Great Britain *Bristol Beaufighter.* (Flight, Vol. 40, No. 1,703, 14/8/41, pp. 90-d.)

79/37 Great Britain *Wellington Mark II (Photograph).* Flight, Vol. 40, No. 1,703, 14/8/41, p. 86.)

79/38 U.S.A. ... *Martin Baltimore and B. 26 (Silhouettes).* (Flight, Vol. 40, No. 1,703, 14/8/41, p. 90e.)

79/39 Great Britain *Bristol Bolingbroke (Photograph).* (Flight, Vol. 40, No. 1,703, 14/8/41, p. 98.)

79/40 Germany ... *Me. 109 F1/2 High Altitude Fighter.* (Flight, Vol. 40, No. 1,701, 31/7/41, p. 62.)

79/41 U.S.A. ... *Curtiss Mohawk and Vultee Vanguard (Silhouette).* (Flight, Vol. 40, No. 1,701, 31/7/41, p. d.)

79/42 U.S.A. ... *Developments in American Types* (*Fortress, Liberator, Catalina, Maryland, etc.*). (Flight, Vol. 40, No. 1,701, 31/7/41, p. f-63.)

79/43 Great Britain *Short Stirling* (*Photograph*). (Flight, Vol. 40, No. 1,701, 31/7/41, p. 64.)

79/44 U.S.A. ... *Martin 187, Baltimore and B-26 Marauder.* (Flight, Vol. 40, No. 1,701, 31/7/41, p. 64.)

79/45 U.S.A. ... *Curtiss Tomahawk* (*Photograph*). (Flight, Vol. 40, No. 1,703, 14/8/41, p. 88.)

79/46 U.S.A. ... *Vultee Vengeance Dive Bomber* (*Photograph*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 163.)

79/47 Great Britain *Wellington II* (*Photograph*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 163.)

79/48 U.S.S.R. ... *Russian Medium Bomber CKB-26* (*Photograph*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 171.)

79/49 U.S.A. ... *Consolidated Catalina* (*Silhouettes*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 172.)

79/50 Japan ... *Japan's Air Power.* (V. L. Grubey, Aeroplane, Vol. 61, No. 1,577, 15/8/41, pp. 174-175.)

79/51 Great Britain *Bristol Beaufighter* (*Photograph*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 181.)

79/52 U.S.A. ... *Bell Airacobra* (*Photograph*). (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 182.)

79/53 Great Britain *History of Machine Gun Synchronisation.* (Aeroplane, Vol. 61, No. 1,577, 15/8/41, p. 188.)

79/54 U.S.A. ... *Curtiss Dive Bomber SB2C-1.* (Inter. Avia., No. 767, 7/6/41, p. 9.)

79/55 U.S.A. ... *Vultee Attack Bomber V-12C and D.* (Inter. Avia., No. 767, 7/6/41, pp. 9-10.)

79/56 U.S.A. ... *Martin Patrol Bomber Flying Boat, PBM-1.* (Inter. Avia., No. 767, 7/6/41, p. 10.)

79/57 U.S.A. ... *North American Single-Seat Fighter XP. 51* (*NA-73* "*Mustang*" *or* "*Apache*"). (Inter. Avia., No. 767, 7/6/41, p. 10.)

79/58 U.S.A. ... *Ballanca Plastic Trainer T-14-14.* (Inter. Avia., No. 767, 7/6/41, pp. 10-11.)

79/59 U.S.A. ... *Fleetwings Basic Trainer XBT-12.* (Inter. Avia., No. 767, 7/6/41, pp. 11-12.)

79/60 Germany ... *German Shelter Buildings.* (Inter. Avia., No. 767, 7/6/41, p. 14.) (Abstract available.)

79/61 Germany ... *Electrical Operation of Time Fuses for Shells.* (G. Grotsch, Z.G.S.S., Vol. 36, No. 7, July, 1941, pp. 135-137.) (Abstract available.)

79/62 Germany ... *Effect of Elevation of Target on Range.* (K. Strange, Z.G.S.S., Vol. 36, No. 7, July, 1941, pp. 140-141.)

79/63 U.S.S.R. ... *Tactical Considerations in the Design of Fighter Aircraft* (*cont. from Vol. 14, No. 12, December, 1940*). (M. P. Stroyer, Aeron. Eng., U.S.S.R., Vol. 15, No. 5-6, May-June, 1941, pp. 8-13.)

79/64 Great Britain/Germany ... *Tail Unit Design in Hurricane and He. 113.* (Flight, Vol. 40, No. 1,705, 28/8/41, p. a.)

79/65 Great Britain *Bristol Beaufighter.* (Flight, Vol. 40, No. 1,705, 28/8/41, pp. f-L.)

79/66 U.S.A. ... *Catalina Taking Off* (*Photograph*). Flight, Vol. 40, No. 1,705, 28/8/41, p. 119.)

79/67 U.S.A. ... *Testing Army Warplanes at Wright Field.* (Automotive Industries, Vol. 85, No. 2, 15/7/41, pp. 24-25 and 70.)

79/68 U.S.A. ... *He. 115 Long Range Bomber (Photograph).* (Autom. Ind., Vol. 85, No. 2, 15/7/41, p. 49.)

79/69 Canada ... *Martin Maryland (Cockpit Photograph).* (Canadian Aviation, Vol. 14, No. 7, July, 1941, p. 19.)

79/70 U.S.A. ... *Catalina Gun Blister (Photograph).* (Canadian Aviation, Vol. 14, No. 7, July, 1941, p. 29.)

79/71 Canada ... *Combat Experience of No. 1 Fighter Squadron (R.C.A.F.).* (Canadian Aviation, Vol. 14, No. 7, July, 1941, pp. 15-17 and 32.)

79/72 Great Britain *Crop Damage by Air Attack.* (J. Russel, Nature, Vol. 148, No. 3,747, 25/8/41, pp. 215-217.)

79/73 U.S.A. ... *Republic P. 47 Thunderbolt (Photograph).* (Aeroplane, Vol. 61, No. 1,572, 11/7/41, p. 32.)

79/74 U.S.A. ... *Consolidated Liberator (B. 24).* (Aeroplane, Vol. 61, No. 1,572, 11/7/41, p. 40.)

79/75 U.S.A. ... *Douglas Havoc Night Fighter (Photograph).* (Aeroplane, Vol. 61, No. 1,572, 11/7/41, p. 41.)

79/76 Great Britain *Rapid Black-Out of a Factory.* (Nature, Vol. 148, No. 3,746, 16/8/41, p. 193.)

79/77 U.S.A. ... *Douglas Boston II (Photograph).* (Aeroplane, Vol. 61, No. 1,572, 11/7/41, p. 46.)

79/78 Germany ... *Aerial Barrages (Barrage Balloons, Aerial Mines and Kites).* (L. Schuttel, published by Lehmann,1939.) (Abstract available.)

79/79 Germany ... *Split Trailing Edge Flaps on Me. 109 F 1/2 (Photograph).* (Flight, Vol. 40, No. 1,702, 7/8/41, p. 75.)

79/80 Great Britain *R.A.F. Floating Rescue Station.* (Flight, Vol. 40, No. 1,702, 7/8/41, p. f.)

79/81 U.S.A. ... *Vought-Sikorsky Chesapeake Dive Bomber.* (Flight, Vol. 40, No. 1,702, 7/8/41, g.)

79/82 U.S.A. ... *Northrop A.17-A Dive Bomber.* (Flight, Vol. 40, No. 1,702, 7/8/41, p. g.)

79/83 Great Britain *Short Stirling.* (Flight, Vol. 40, No. 1,702, 7/8/41, p. 80.)

79/84 U.S.A. ... *Lockheed Vega 37 (Ventura) (Photograph).* (Aeroplane, Vol. 61, No. 1,578, 22/8/41, p. 190.)

79/85 Great Britain *Accidents to Liberators Engaged on Ferry Service.* (Aeroplane, Vol. 61, No. 1,578, 22/8/41, p. 190.)

79/86 U.S.A. ... *Consolidated Model 28-5 Catalina (Photograph).* (Aeroplane, Vol. 61, No. 1,578, 22/8/41, p. 194.)

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79/561 U.S.A. ... *The CAA-MIT Microwave Instrument Landing System.* (E. L. Bowles, W. L. Barrow and others, A.I.E.E. Trans., Vol. 59, 1940, pp. 859-864.) (Abstract available.)

79/562 U.S.A. ... *Calculation of the Radiation Properties of Hollow Pipes and Horns.* (J. L. Chu, J. of Applied Physics, Vol. II, No. 9, Sept., 1940.) (Abstract available.)

79/563 U.S.A. ... *Centimetre Waves Coming Up.* (F.D.L., QST., Amateur Radio, Vol. XXIV, No. 10, p. 32.) (Abstract available.)

79/564 U.S.A. ... *Three Spots and a Horn (Irving Metcalf's Blind Landing System).* (D. Fink, Aviation, Vol. 37, No. 9, Sept., 1938, pp. 28-29 and 73-74.) (Abstract available.)

79/565 U.S.A. ... *Electro-Magnetic Waves in Hollow Metal Tubes of Rectangular Cross Section.* (J. Chu and W. L. Barrow, Procs. of I.R.E., Vol. 26, No. 12, Dec., 1938, pp. 1,520-1,555.) (Abstract available.)

79/566 U.S.A. ... *The Corner Reflector Antenna.* (J. D. Kraus, Procs. of I.R.E., Vol. 28, No. 11, Nov., 1940, pp. 513-519.) (Abstract available.)

79/567 U.S.A. ... *The Characteristics of the Negative Resistance Magnetron Oscillator.* (H. Chang and E. L. Chaffee, Procs. of I.R.E., Vol. 28, No. 1, Nov., 1940, pp. 519-523.)

79/568 Great Britain *Metal Rectifiers.* (Engineering, Vol. 152, No. 3,940, 29/8/41, p. 172.)

79/569 U.S.A. ... *Theoretical and Experimental Investigations of Electron Motions in Alternating Fields with the Aid of Ballistic Models.* (H. E. Hollmann, Procs. of the I.R.E., Vol. 29, No. 2, Feb., 1941, p. 70.)

79/570 Great Britain *Magnetic Penetration.* (T. F. Wall, Engineer, Vol. 172, No. 4,470, 12/9/41, pp. 166-167.)

79/571 U.S.A. ... *Electro-Magnetic Horn Design.* (L. J. Chu and W. L. Barrow, A.I.E.E. Trans., Vol. 58, July, 1939, pp. 333-338.) (Abstract available.)

79/572 U.S.A. ... *Biconical Electro-Magnetic Horns.* (W. L. Barrow and others, Proc. of I.R.E., Vol. 27, Dec., 1939.) (Abstract available.)

79/573 U.S.A. ... *Aircraft Radio.* 1939. (Electronics, Jan., 1939, pp. 10-14 and 43.) (Abstract available.)

79/574 U.S.A. ... *The Sectoral Electro-Magnetic Horn.* (W. L. Barrow and F. D. Lewes, Proc. I.R.E., Vol. 27, No. 1, Jan., 1939, pp. 41-50.) (Abstract available.)

79/575 U.S.A. ... *Theory of the Electro-Magnetic Horn.* (W. L. Barrow and L. J. Chu, Procs. I.R.E., Vol. 27, No. 1, Jan., 1939, pp. 51-64.) (Abstract available.)

79/576 U.S.A. ... *New Power for Ultra High Frequencies.* (D. G. Fink, Aviation, March, 1939, pp. 62-63.) (Abstract available.)

79/577 U.S.A. ... *An Oscillator for Ultra-High Frequencies.* (W. L. Barrow, Rev. Scient. Insti., Vol. 9, June, 1938, pp. 170-174.) (Abstract available.)

79/578 U.S.A. ... *Characteristics of a Split-Anode Magnetron Oscillator as a Function of Slot Angle.* (Leo Rosen, Rev. Scien. Insti., Vol. 9, Nov., 1938, pp. 372-373.) (Abstract available.)

79/579 Great Britain *The Generation and Amplification of Micro Waves.* (C. E. Lockhart, Electronic Engineering, Vol. 14, No. 162, 1/8/41, pp. 336-338 and 347.)

79/580 Great Britain *Review of Progress in Electronics, V (Photo Electricity).* (J. Windred, Electronic Engineering, Vol. 14, No. 162, pp. 345-347.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the

Directorates of Scientific Research and Technical Development, Air Ministry.

(Prepared by R.T.P.)

No. 95. October, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

Requests from scientific and technical staffs for further information or translations should be addressed to R.T.P.3, Ministry of Aircraft Production.

Only a limited number of the articles quoted from foreign journals are translated and usually only the *original* can be supplied on loan. If, however, translation is required, application should be made in writing to R.T.P.3, the requests being considered in accordance with existing facilities.

Note.—As far as possible, the country of origin quoted in the items refers to the original source.

List of Abbreviations of Titles and Journals.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automoline Industries.
Autom. Tech. Zeit. ...	Automobiltechnische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Elektroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.

J. Frank. Inst.	Journal of Franklin Institute.
J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
J.S.A.E.	Journal of Society of Automotive Engineers.
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Ausiandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Veröffent (Siemens)	Veröffentlichungen aus dem Gebiete der Nachrichtentechnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatshefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für das gesamte Schiess- und Sprengstoffwesen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

On the Calculation of the Impact Force of Bombs. (F. Frey, Schweiz Techn. Zeitsch, No. 24, 13/6/40, pp. 293-294.) (95/1 Switzerland.)

The author considers the special case of a bomb of mass M striking the centre of a beam of length l. The beam is assumed to be freely supported at its ends of uniform cross-section and of total mass m. If the impact is completely inelastic, the kinetic energy L of the combined system is given by

$$L = \tfrac{1}{2} M^2 V^2 / (M + M^1)$$

where M^1 = reduced mass of beam

$= (17/35)\ m$ and V = velocity of bombs at impact.

By equating this to the elastic work of deformation, it can easily be shown that the equivalent static load P is given by

$$P^2 = \frac{96\, EIL}{l^3}$$

From this the max. stress σ in the beam follows

$$\sigma = \frac{Pl}{4\, W}$$

where W = section modulus.

If the beam is short and wide a correction has to be applied for the lateral forces.

From the above, the author concludes that best protection against bomb impact is provided if the mass of the ceiling is as large and at the same time the mounting as flexible as possible. For this purpose he recommends a hinged frame construction supported on vertical pillars. It should be pointed out that the problem is considered purely from the point of view of mechanical impact and no consideration is given to explosive effects.

Reconditioning of War-Damaged Machine Tools. (Machinery, 18/9/41, pp. 673-681.) (95/2 Great Britain.)

The article describes methods employed in the Ministry of Supply Reconditioning Scheme to repair machines, damaged either by enemy action, or those worn in service. Machines damaged by high explosives are generally less difficult to deal with than those damaged by fire. Not only are the latter usually out of alignment, but they have lost their original heat-treated properties. The replacement by welding or re-casting of broken or buckled castings is described, as well as the loosening of solidly-corroded moving parts. Worn parts may be built up by metal spraying. Many details are given of checking the alignment of bedways, tables and spindles, including makeshift emergency repairs.

(Abstract supplied by Research Dept., Met. Vick.)

Military Aircraft Production in the U.S.A. during 1941. (Senator Byrd, American Aviation, Vol. 5, No. 7, Sept., 1941, pp. 1 and 15.) (95/3 U.S.A.)

	Total production by U.S. Military Aircraft Mfrs. (Official O.P.M. figures).	Military (combat plus trainer).	Combat.	Trainer.	Non-military (exclusive of combat, trainer and light planes).
January ...	1,036	957	502	455	79
February ...	972	879	415	464	93
March ...	1,216	1,056	552	504	160
April	1,389	1,357	693	664	32
May	1,334	1,258	650	608	76
June	1,489*	1,473	698	775	16
July	1,460	1,455	700†	755	5
Totals... ...	8,896	8,435	4,210	4,225	461

* OPM officially reported 1,476 for June. Above figure is correct.

† Approximate. (Of this total less than 300 were bombers of all kinds. Production of long-range bombers does not exceed 60 a month.)

Relaxation Methods Applied to Engineering Problems. VII, Percolation of Fluids Through Porous Media. (F. S. Shaw and R. V. Southwell, Procs. Roy. Soc., Vol. 178, No. 972, 9/5/41, pp. 1-17.) (95/5 Great Britain.)

The accepted theory of percolation of fluids through porous materials (which is based on Darcy's law of resistance) indicates that the velocities can be calculated from a velocity-potential which, in two-dimensional motion, is plane-harmonic within the fluid field. The associated stream function, and the fluid pressure, are also plane-harmonic, so in cases where all boundaries are known, their determination is an ordinary problem in plane-potential theory. But in cases where a free surface exists (as in the percolation of water through earth dams), its shape is not known a priori, consequently orthodox methods cannot be applied.

Here the relaxation method developed in earlier papers is shown to be applicable without special assumptions, and to yield results of more than sufficient accuracy. Three typical examples are treated, the third involving " refraction " of the lines of flow and pressure at the junction of two materials of different porosity.

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Experiments at Supersonic Speed on a Biplane Arrangement of the Busemann Type. (A. Ferri, Atti di Guidonia, No. 37-38, 10/11/40.) (95/6 Italy.)

Following brief description of the experimental supersonic biplane and the experimental procedure, the author gives the results obtained by means of optical observation, the measurement of the pressures and the determination of the forces on a symmetrical biplane system for different wing-gap values. The experimental results are compared with those obtained by calculation and the causes of the discrepancies found between them are discussed.

Compressibility Effects in Aerodynamics. (Th. von Kármán, J. of Aeron. Sciences, Vol. 8, No. 9, July, 1941, pp. 337-356.) (95/7 U.S.A.)

The author reviews the various methods available for the mathematical treatment of supersonic flow in an ideal compressible fluid. Of special interest are expressions for the critical Mach number as a function of the maximum suction-pressure coefficient at low speeds applying to the case of an aerofoil (NACA 4412), and elliptic and circular cylinder respectively. The results are in fair agreement with experiment. Whilst thus the first coincidence between local velocity and local sound velocity can be predicted with fair accuracy in a number of cases, it is not by any means certain that this is necessarily associated with the appearance of a shock wave in an ideal fluid. Recently Ringleb (ZAMM Vol. 20, 1940, pp. 185/198) has found exact flow patterns of compressible gases in which the flow velocity reaches 1.6 times the value of sound and becomes subsonic again without shock losses. In the practical case of a real fluid it is scarcely likely that shock can be avoided altogether and it may be that the flow with shock is more stable than the continuous flow pattern. The mathematical analysis however indicates that the mere passage of the air at supersonic speeds does not necessarily imply energy loss by shock and that it may thus be possible to increase flying speeds considerably above present values before the wave resistance becomes important.

An extensive bibliography (52 items) concludes the article.

Temperature Effects in a Laminar Compressible Fluid Boundary Layer Along a Flat Plate. (H. W. Emmons and J. G. Brainerd, J. App. Mech., Vol. 8, No. 3, Sept., 1941, pp. 105-110.) (95/8 U.S.A.)

In this Paper the two-dimensional boundary-layer problem of the steady laminar flow of a perfect gas along a thin flat insulated plate has been solved for a wide range of gas velocities and properties by means of the differential analyser. It is found that compressibility and Prandtl number do not introduce any new phenomena, but do alter the drag on the plate, the equilibrium temperature of the plate, and the velocity and temperature distribution through the boundary layer.

The solutions of the boundary layer problem are of the same general nature for fluid velocities above and below that of sound.

In order to pass the plate, the main stream must acquire a velocity component perpendicular to the plate. At speeds below that of sound, the requisite turning angle is produced by a slight modification of the potential flow. At supersonic speeds, the turn is accomplished by a small oblique compression shock which, for practical purposes, appears as two Mach lines trailing from the leading edge of the plate.

The main conclusions reached are:

1. An increase in viscosity with temperature does not cause a proportional increase in the drag of the plate, since the velocity profile is also altered.
2. With increase in the ratio of thickness of Prandtl number velocity layer $\delta\mu$ to temperature layer δ_T increases, *i.e.*

$$\frac{\delta\mu}{\delta_T} = P_r^{\frac{1}{2}}$$

3. Increase in compressibility number leads to a large increase in the lateral flow component due to the combined effect of increase in density and temperature near the surface of the plate.

Heater for Winter Starting. (Aeroplane, U.S.S.R., Vol. 17, No. 23-24, Dec., 1940, p. 17.) (95/10 U.S.S.R.)

In the winter training of pilots it will be found useful to have a mobile starting unit consisting of a car or carriage of tramway type, accommodating about twenty men. It is heated by an iron stove and mounted on four runners of usual aircraft type, enabling it to be easily moved about the aerodrome. In winter conditions, especially prior to long-distance flights, such a heater is indispensable; the starting personnel can keep warm, and the pupils have an opportunity to change and prepare themselves for their flight.

The equipment of the car includes a small bench and tools for running repairs and a table for the time-keeper. Lockers under the seats accommodate starting equipment, pilots' and navigators' instrument bags, etc.

The entrance is in the form of a small vestibule, to keep out draught, and for the storage of fuel.

The construction of the car is of wood; interior, finish and equipment can be adapted to any particular requirements.

In conjunction with the above, a heating stove for warming up engines is described. It is made of sheet iron and heated with charcoal. When the stove has burned through and no flame appears, it is placed under a hood covering the engine. By this means, even in frost of 40°, an engine of M-11 type could be heated up to +60/70° in 20 minutes. The stove is simple in construction and safe in operation.

The devices described have been put in use by several aero-clubs in the U.S.S.R.

Winter Starting. (Aeroplane, U.S.S.R., Vol. 18, No. 2, Feb., 1941, pp. 25-27.) (95/11 U.S.S.R.)

Describing methods and appliances developed by a Moscow flying club to enable training to continue throughout the winter.

Firstly, care was taken to have the complete lubricating system of the aircraft insulated from the cold. The insulations consisted of felt cloth and aeroplane fabric or tape. This is treated in turn with two ground coats and two finishing coats of paint. By this means it was possible to keep the oil temperature at 65/70°, even in prolonged glides.

The oil/water heaters supplied have a capacity sufficient for simultaneous treatment of all the aircraft in service.

The oil is fed into the inner case through a special nozzle on the can, and not through a funnel, avoiding waste, soiling and cooling off.

The simple charcaol-fired heaters used are of the type described in the previous abstract (95/10). They have been fitted with an additional spark retainer, further decreasing the fire risk. They are extremely simple and cheap to operate. No petrol is required.

The stoves are also used to give the flying personnel and ground staff an opportunity to warm themselves before taking off.

The starting (heating) hoods used on the engines are of standard type, but additionally lined with wadded fabric. The cylindrical portion (tube) of the hood is distended by two wire rings, to prevent contact with the hot stove. The number of stoves and hoods is sufficient to serve all the aircraft stationed on the aerodrome at one time.

The stoves take 1-15 minutes to heat up and are started about one hour before the flights are to begin.

At the end of the operations for the day, a special collector receives the oil remaining in the engines. The aircraft are re-fuelled and ready for the next day.

The Pre-Flight Reflex Trainer. (B. H. Pearse, U.S. Air Services, Vol. 26, No. 8, Aug., 1941, pp. 16-17.) (95/12 U.S.A.)

The pre-flight reflex trainer consists principally of a canvas-covered cockpit suspended in a triangular frame which is mounted on wheels and powered with a 1½ h.p. motor. Seated at the controls, the student travels at about 12 m.p.h. around a large concrete platform, making turns and banks, glides and climbs, and figure eights, trying to avoid tripping the warning horn which blares forth whenever he overbanks or makes a mistake in co-ordinating the controls.

The combination of forward motion together with the turning and banking of the cockpit gives the student the feel of a plane in a way that a stationary device cannot do. And to the student concentrating all his mental effort on trying to make his hands and feet work together instead of at cross purposes, 12 miles an hour may seem quite fast enough.

Another advantage of the device's mobility is its adaption for machine gun practice. The gun trigger operates a 22-calibre weapon mounted on the forward part of the cockpit so that control and operation of a machine gun can be practised in conjunction with operation of the usual flight controls. With installation of certain instruments and a hood, it can also be adapted to instrument flying training.

Just how much time could be saved by widespread use of such a device as the pre-flight reflex trainer, of course only a test will show. The importance of saving even an hour or two in a vast training programme affecting 10,000 and more students is obvious.

General Approach to the Flutter Problem (with Discussion). (S. J. Loring, J.S.A.E., Vol. 49, No. 2, Aug., 1941, pp. 345-350.) (95/13 U.S.A.)

A general approach to the flutter problem is outlined, which can be used to investigate any mode of flutter of any structure, provided the air forces are known.

The method can be used to investigate the possibility of flutter on such structures as aeroplane wings and tail surfaces, bomb doors, aircraft propeller blades, vehicular bridges, buildings, etc.

Starting with a well-known solution for the air forces for two-dimensional flow over an airfoil with an aileron, equations have been derived which can be used to determine the flutter speed for the wing or tail surfaces of any conventional airplane.

The use of still-air vibration tests in obtaining the structural friction of structures, and in checking a part of the flutter computations experimentally is indicated.

Finally, to suggest the possibilities in the use of this method, a standardized procedure for its general application to aircraft flutter problems is outlined briefly.

New Parachute Design Drop Tested. (Aviation, Vol. 40, No. 7, July, 1941, p. 127.) (95/14 U.S.A.)

Incorporating a new principle in construction, a parachute made by Dr. Christian A. Volf of New York, N.Y., was drop-tested recently in Glendale, Calif.

By means of an inverted cone, rate of descent is said to be decreased and greater stability obtained, thereby overcoming drift in a high wind. A further object in the new design has been to reduce the size of the present standard parachute and so cut down materials and bulk.

According to the inventor, maximum strain on the parachute exists at the outer edges where the greatest shock is absorbed upon opening. As a result of the cone, the apex, which becomes the point of attack, tends to build up an air velocity towards the centre of the canopy, about four times greater than rate of descent. The high velocity air strikes the canopy over an area where maximum tensile strength prevails.

The inventor expects to build a parachute only 15 feet in diameter having additional vents situated in the canopy to permit release of the high-velocity air moving into the canopy as a result of the cone. It is expected that this size will be sufficient to carry down a 220-lb. pilot at a speed not exceeding 18 feet per second, and that the present pilot parachutes can be eliminated because of the cone.

Boeing Strato-Chamber. (Aviation, Vol. 40, No. 7, July, 1941, p. 127.) (95/15 U.S.A.)

Group training of flight crews for extreme altitude test work is being carried out by Boeing Aircraft with a sealed tank which reproduces flying conditions at 35,000 feet.

With both Britain and Germany building planes for combat at altitudes of seven miles, pilots will require careful training and " stratosphere conditioning " will be a necessity. Boeing's strato-chamber will prepare a whole crew of trained engineers to go into the stratosphere to gather test data on the operation of turbo-superchargers in the Boeing B-17 type.

It has been found that if a man's oxygen supply is cut off at 20,000 feet, he will pass out in ten minutes. At 25,000 feet unconsciousness comes in three minutes, and at 29,000 feet the flyer passes a critical point at which loss of oxygen means unconsciousness in less than one minute.

Above 35,000 feet an oxygen mask may furnish enough pure oxygen, but the rarified atmosphere does not supply enough lung pressure, and breathing is as difficult at 40,000 feet with a mask as it would be at 18,000 feet without one. Thus 40,000 feet seems to be the limit of human endurance without pressure cabin-equipped planes or pressurized suits and helmets.

The strato-chamber can reproduce flight conditions up to 40,000 feet and can accommodate three trainees and their equipment. Vacuum pumps reduce inside pressure to the equivalent of atmosphere pressure at any altitude. To guard against " aeroembolism " (an effect similar to a diver's " bends ") pure oxygen is preathed previous to the flight to " denitrogenize " the blood. The trainees then enter the tank wearing complete flying equipment; the door is closed, pumps start, and the flyers begin their " journey " to 35,000 feet. At various altitudes they practice handling their equipment under simulated emergency conditions.

As a result of the strato-chamber tests, the Mayo Laboratory of Aviation Medicine has adopted the Boeing check-off list for stratosphere flight crews. This list is a step-by-step procedure for crews to follow in preparing for any flight above 25,000 feet.

Aircraft Electricity as the Air Line Operator Sees It. (P. C. Sandretto, J.S.A.E., Vol. 48, No. 4, April, 1941, pp. 154-159.) (95/17 U.S.A.)

The electric power consumption in the DC-3 transport aircraft on a five hours' flight is analysed. Of the total consumption, about 73 per cent. is used for navigational purposes, 19.8 for service and 7.2 for operations. Details appear in the following tables.

TABLE 1—Operation Electricity, Douglas DC-3 Plane.

	Amp.	Amp.-Min.
Warning lights	1.2	360
Landing-gear warning lights...	0.7	210
Engine starters...	260.0	520
Fuel and oil pressure warning lights	1.1	66
Booster coils	3.0	6
Total		1,162

TABLE 2—Avigation Electricity, Douglas DC-3 Plane.

	Amp.	Amp.-Min.
Windshield defroster fan	1.0	300
Argon dynamotor and/or instrument spot-light	1.5	450
Pilot heater	14.0	4,200
Running lights	2.5	750
Compass, gyro and radio panel lights	1.0	300
Instrument panel lights	1.0	300
Radio-receiving dynamotor and receiving filament	7.3	2,190
Electrical instruments	1.0	300
Wing de-icer	1.5	450
Transmitting dynamotor	60.0	900
Transmitting filaments	15.0	450
Landing lights	70.0	1,050
Baggage pits	2.0	90
278-kc. relay	0.4	2
Total		11,732

TABLE 3—Service Electricity, Douglas DC-3 Flares.

	Amp.	Amp.-Min.
Cabin side lights	6.2	1,800
Buffet lights	1.0	300
Cabin warning lights	2.5	100
Seat belt warning	1.2	360
Companionway domelight	1.0	45
Stewardess call light	1.0	5
Cabin light relay	0.5	30
Cabin dome lights	6.2	372
Entrance door light	1.7	105
Total		3,177

The source of supply consists of two 12 v. d.c. generators and two 65 amp. h.v. storage batteries. The total weight is about 190 lb., or 127 lb. per kw., on a continuous rating of 1.5 kw. (the weight of cable and conduits is of the order of 300 lb.).

On the DC-4 (55,000 lb. gross weight against 25,000 lb. of the DC-3), by stepping up to 24 volt and various other improvements, such as speeding up generators, it has been possible to obtain a continuous rating of 20 kw. for a weight of only 242 lb., *i.e.*, the specific weight has been reduced to about 20 lb. per kw., whilst the conduit system weighs about 540 lb.

The author is of the opinion that 24 v. d.c. will remain standard for some time, but that for much larger machines (gross weight ~ 100,000 lb.) a.c. current at 115 volts and frequencies ranging from 300 to 900 cycles will enable a further marked reduction in weight of the electrical power plant.

Field of View from the Pilot's Cockpit. (A. Vannucci, Atti di Guidonia, No. 42, 30/1/41.) (95/16 Italy.)

A description is given of a method for the determination of the pilot's field of view obtained by the cylindrical projection on a sheet of sensitized paper. The corrections to be made owing to the distortion of the co-ordinate grid system are calculated and applied.

The Use of Liquid Oxygen for High Altitude Flying. (J. D. Ackerman, J. Aeron. Sci., Vol. 8, No. 9, July, 1941, pp. 361-364.) (95/18 U.S.A.)

A method and apparatus is described to produce gaseous oxygen from liquid oxygen for use in high-altitude flying. The elimination of the danger of dis-

continuity of oxygen boiling and provision for securing the required volume of oxygen gas is accomplished by keeping the liquid oxygen under a pre-determined pressure and supplementing the normal evaporation by spilling a necessary amount of liquid oxygen in the gas contained. Fast evaporation takes place to maintain a constant supply of oxygen gas inside the apparatus which is connected with a second-stage reducing valve of a B-L-B oxygen mask as developed by the Mayo Foundation.

To secure the spilling of liquid oxygen into the gas container, an absolute pressure-valve is provided in the gas contained, to keep a pre-determined pressure of gas in the liquid container. The liquid container does not require the use of a vacuum bottle. Although no attempt is made to design the apparatus for any specific aeroplane, the mechanism is flexible for adaptation to meet any specific requirements of oxygen supply. Apparatus for handling and storing liquid oxygen and the possibilities of a portable liquid oxygen-producing plant are discussed.

Effect of Compass Location in Aircraft in Dynamic Errors. (W. Wrigley, J. Aeron. Sci., Vol. 8, No. 9, July, 1941, pp. 365-367.) (95/19 U.S.A.)

A compass may be located, either for convenience or necessity, at some distance from the centre of gravity of large modern aircraft. Such a location may give rise to dynamic errors in the readings of the compass due to the accelerations of roll, pitch and yaw of the aeroplane about its centre of gravity. The acceleration of yaw is probably the most serious factor in producing such dynamic errors regardless of whether the compass is located in the nose, the tail, or in a wing.

The magnitude of the dynamic errors in compass readings increases in an approximately linear fashion as the distance of the compass from the centre of gravity of the aeroplane is increased. For any particular location of the compass there will be a certain heading of the aeroplane for which the compass reading will have a maximum error. The dynamic errors may exist as magnitude effects of up to several degrees, or as phase effects of up to almost one hundred an eighty degrees.

Systematic Tank Experiments on a Twin-Float Seaplane, Type "G.I.S. 6," for Different Conditions of Trim and Loading and Distance between Floats. (Cremona Cesare, Atti di Guidonia, No. 20, 20/12/39.) (95/20 Italy.)

The modern non-dimensional method is of experimentation applied to the problem of seaplane floats, both single and in pairs.

In the first part of the report, the author describes the new method and gives the results of a complete series of experiments carried out in the Guidonia tank (load, speed, drag, trim, distance between floats).

From these a general picture is presented, both of the experimental difficulties, and of the wide choice of data open to the designer and the mathematician.

M.I.T. Wright Brothers Wind Tunnel and its Operating Equipment. (J. R. Markham, J.S.A.E., Vol. 49, No. 3, Sept., 1941, pp. 380-388.) (95/25 U.S.A.)

With the M.I.T. Wright Brothers wind tunnel and balance system it is possible to obtain measurements very rapidly on a complete aeroplane model from which the coefficients for all six components can be plotted with a minimum of calculation. It is usually possible to mount the model so that the point representing the centre of gravity of the aeroplane is on the balance axis, a feature which increases the accuracy of the results and the simplicity of the calculations.

The balance system was designed to fulfil the following general specifications: It has to be compact for the pressure-type tunnel in which it operates so that the shell surrounding the test section be kept to a minimum diameter; it should be arranged so that measurements of all six components could be made remotely and that angular settings of the model in pitch and yaw could be made from

a remote station. It was required further that each component be measured independently and totally so as to simplify and shorten the numerical calculations.

The test section was made an ellipse in order to obtain as large a span-wise dimension as possible for a given test-section area. It is then possible, without requiring extra power, to test a model with a larger span in an elliptical tunnel than in a tunnel of circular cross-section of the same area at the same speed.

Icing Problems in Operation of Transport Aircraft. (R. L. McBrien, J.S.A.E., Vol. 49, No. 3, Sept., 1941, pp. 397-408.) (95/26 U.S.A.)

The information given in this Paper was obtained principally from trip icing logs and test flights conducted on a major transport system. A copy of a trip icing log is included to show the type of information obtained from normally scheduled flights.

The different types of ice formed are explained and the general effect upon the performance on the aeroplane for each type of ice is stated.

Aeroplane ice accumulations are divided into two major classes: (1) Those producing a loss of flight performance and (2) those which serve as an annoyance to the crew. The main portion of the Paper deals with these two classes, explaining when, how and why they are of importance. Numerous pictures are shown depicting the various conditions which were found to exist in scheduled airline operations and the shortcomings of the present anti-icing equipment is explained.

Consideration is given to ice accumulations on the wings, empennage, propeller, pitot mast, radio loops, windshield, and so on. It is hoped that a dissemination of these actual airline operating conditions and experiences will result in further improvements to airline and anti-icing equipment. It is also hoped that instrumentation means will be developed whereby ice accumulations can be better analyzed and reported.

Standardisation of Liquids Employed in the Hydraulic Controls and Shock Absorbers of Aircraft. (V. Ceccarini, Atti di Guidonia, No. 39-40, 10/12/40.) (95/27 Italy.)

After a reference to the absolute necessity of standardizing the liquids employed for shock absorbers and hydraulic systems on aircraft, the author gives the characteristics of the most important existing liquids and then considers the castor oil + diacetone alcohol mixture which, of the liquids in use, appears to be of the greatest interest.

The three mixtures of castor oil and diacetone alcohol prepared in the laboratory for jacks, oleo-pneumatic and oleo-elastic shock absorbers are examined. Descriptions are given of the chemical and physical tests carried out on these mixtures in order to ascertain their behaviour under service conditions, and of a method for the determination of their action on the metals and the rubber used in the fittings. The results are discussed also with respect to the possibilities of employing mineral oils, the other highly important group of liquids and perhaps the only one which may present real advantages over the castor-diacetone mixtures.

A scheme of standardization for the mixtures is suggested.

In conclusion, the relative advantages of castor oil + diacetone alcohol mixtures and of mineral oils are compared. The latter are found to be preferable provided the viscosity characteristics are suitable.

Compounding—Facts and Fallacies. (F. L. Prescott, J.S.A.E., Vol. 49, No. 2, Aug., 1941, pp. 326-331.) (95/28 U.S.A.)

The 2-Cyl. "Compound" engine with spark ignition on which the data reported in this Paper were obtained is provided with a high-pressure cylinder and a low-pressure cylinder which serves as a compressor as well as a working cylinder.

The primary consideration in this work was the extracting of additional work from the already partially expanded gases from the high-pressure cylinder; a secondary consideration was the use of the same low-pressure cylinder as a second-stage compressor to aid in supercharging the high-pressure cylinder.

In reporting test results covering the development and testing programme on the 2-Cyl. test unit, indicator diagrams showing the power developed in both high-pressure and low-pressure cylinders are presented. Some results and conclusions follow:

1. An indicated m.e.p. of 705 psi was recorded in the high-pressure cylinder but the corresponding i.m.e.p. in the low-pressure cylinder was only 63 psi.
2. Fuels are available which make possible mean effective pressures in the high-pressure cylinder, resulting in release pressures to the low-pressure cylinder of 350 to 400 psi.
3. Two-stage expansion to a final ratio of 15:1 or more is feasible.
4. Modern internally cooled valves are satisfactory even under the unusual temperature and pressure conditions encountered by the high-pressure exhaust valve.
5. Compounding the expansion results in a definite increase in thermal efficiency.
6. The brake thermal efficiency is however poor, due to friction losses in the low pressure piston compressor.

Waste Heat Recovery with Vapour-Phase Cooling. (J. H. Wallace, J.S.A.E., Vol. 48, No. 4, April, 1941, p. 159.) (Digest.) (95/30 U.S.A.)

Based on heat input, present day internal combustion engines average about 25 per cent. efficiency, the heat distribution being roughly as follows:—

Shaft h.p.	...	...	...	26 per cent.
Jackets	...	...	...	28 ,,
Exhaust	...	...	...	34 ,,
Friction	...	...	...	6 ,,
Radiation	...	...	...	6 ,,

Exhaust waste heat boilers can recover between $2\frac{1}{4}$ and $2\frac{1}{2}$ lb. of steam per b.h.p. hour. The apparatus is, however, excessively bulky and subject to corrosion troubles.

By use of the vapour-phase system of cooling, as much as $5\frac{1}{2}$ lb. of steam can be generated per b.h.p. hour at full load and the steam can be delivered at pressure between 5 and 20 lb. per sq. in. without any marked change in present day engine design. The main features requiring attention are the gaskets and liner packing. By using neoprene or duprene sealing rings, the temperature at the liner joints can be raised to 350°F. without difficulty.

Altitude Performance of High Output Aircraft Engines. (R. N. Du Bois, J.S.A.E., Vol. 48, No. 4, April, 1941, pp. 138-147.) (95/29 U.S.A.)

Starting off with laboratory tests covering the b.h.p. and motoring losses of a single cylinder engine over a wide range of inlet and exhaust conditions, the author calculates the altitude performance of the same engine at various degrees of boost, *i.e.*, supercharger drive ratio. The supercharger is assumed to have a compression efficiency of 66 per cent. and a 10 in. impeller. Curves connecting impeller tip speed and compression ratio at various inlet temperatures are assumed to be available as well as pressure drop at intake to blower as a function of rate of air flow. Polytropic compression with the exponent $n = 1.67$ is assumed. The final manifold pressure and temperature gives the indicated power from the engine calibration chart. This is converted into the corresponding air consumption and the blower h.p. calculated. The engine friction h.p. is defined as the power

required to overcome mechanical friction and pumping losses at the intake and exhaust pressures under consideration. (Under high degrees of boost, the friction h.p. may be negative, *i.e.*, the engine is being driven by the exhaust/inlet pressure difference.) Deducting friction and blower h.p. from the indicated h.p., the b.h.p. at altitude is finally obtained.

The author also considers the case when a two-speed single stage, a two-stage single speed, or a two-speed two-stage blower is employed respectively. Of special interest is the proposal to have the first stage driven independently by means of an auxiliary engine, whilst the second stage is coupled permanently to the main power plant.

For a given brake output to the propeller, the indicated h.p. of the main engine is less in this arrangement and this is an advantage when working near the limiting cylinder output.

American Experience with Buchi Supercharging. (J. P. Stewart and other, J.S.A.E., Vol. 49, No. 3, Sept., 1941, pp. 389-930.) (95/32 U.S.A.)

Buchi turbo-charged engines are suitable for practically any class of service where a Diesel engine is used. This system of supercharging at present has its greatest usefulness with those engine builders who do not manufacture a few standardised engines in production quantities such as the automotive type, but who have a number of available standard sizes which are adapted to specific requirements in each case. This enables them to offer for sale normally aspirated engines when suitable and turbo-charged engines when required, with a few changes from the standard engine construction. With the positive-pressure blower, a mechanical drive must be provided requiring in the neighbourhood of 6 to 10 per cent. of the total output of the engine. In many cases the normal camshaft drives are not designed to carry such a load, nor is space available for the blower without affecting overall dimensions.

The question naturally arises as to the future possibilities or trends with respect to supercharged engines. The indications are that supercharged engines must be used increasingly in the future, and it is not inconceivable that the time will come when practically all four-cycle engines will not only be supercharged in some form, but will be designed specifically for supercharging. The most important reason for supercharging is, of course, to obtain more output per total less weight and space. At the present time, a cost saving in dollars per total horse-power due to using supercharging can be shown, but it is not of great magnitude. However, there are good reasons to believe that costs will develop to be more and more in favour of the supercharged engine as time goes on and supercharging is more universally used.

The ultimate possibilities of supercharging are still very largely unexplored. A still greater degree of supercharging is possible with the single-stage turbo-charger blower than is now being used commercially. Multi-stage blowers with higher charging pressures, coupled with advances in metallurgy to permit higher operating temperatures, are a further possibility.

One hundred and forty psi b.m.e.p. is already attainable with existing temperature limits. This is by no means the limit, but undoubtedly additional problems will remain to be solved in the development of even higher b.m.e.p. values. Also, as the degree of supercharging is increased, the greater quantity of fuel burned in the cylinder will bring new combustion problems. No doubt increasingly higher piston speeds will also be used in conjunction with higher values of b.m.e.p., and these will bring their own problems in connection with the mechanical design of the engine. To sum up, it is felt that the four-cycle supercharged Diesel engine is now on the verge of a rapid evolution toward a substantial reduction in specific weight and space, although these objectives will be accomplished only by considerable research and field operating experience.

Design Feature and Performance Characteristics of the Mercedes Benz D.B. 601A Aircraft Engine. (R. W. Young, S.A.E. Journal, Vol. 49, No. 1, July, 1941, pp. 22-23.) (Digest with Discussion.) (95/33 U.S.A.)

From a review on contemporary American, British, French and German aircraft engines, it appears that German and French liquid-cooled designs tend towards larger displacement and lower crankshaft speeds than those current in Britain and the U.S.A. At the same time the b.m.e.p. under military rating is about 6 per cent. lower. Nevertheless, the performance of the D.B. 601 with regard to sea level and altitude power, fuel consumption and weight is on a par with best existing designs.

No useless effort in man hours or finish has been expended where there is not a direct return in increased reliability or performance. The handiwork in polishing and finish of all highly stressed parts is however of the highest order.

The fuel injection system and fluid drive are of special interest. The mixture control for altitude is stated to be complicated but reliable. The workmanship is excellent and ensures smooth operation of the control. The magnetos employed weigh only about half as much as the standard American product. Servicing is rendered easy by a number of clever devices preventing loss of small parts on disassembly. All screws not necessarily to be touched have their slots covered with white paint.

(The paper has been published in full in "Aircraft Engineering," Oct., 1941, pp. 270-279.)

A New High Altitude Fuel System for Aircraft. (W. H. Curtis and R. R. Curtiss, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 200-205.) (95/34 U.S.A.)

This paper deals in a general way with a brief history of the work that has been done in the past on aircraft fuel systems to adapt them for high altitude flight, the reasons for failures that developed, some of the physical aspects of aircraft fuel at high altitude, and a brief description of the Thompson booster system.

This system was evolved as the result of the application of analytical reasoning to the fuel systems that preceded it. The booster unit is a modified centrifugal pump, attached directly to the fuel tank and driven by an electric motor. Its function is to prevent entrance of released vapour and air to the fuel line leading to the fuel pump on the engine. It also maintains sufficient pressure in this line to prevent additional release of air vapour.

Standardisation of Aircraft Engine Components. (G. Carvelli, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 294-300.) (95/35 U.S.A.)

Standardization of engine components should start in the drafting room with use of a system of sample drawings, and dimensioning of parts should be simplified through use of a two-place decimal system.

The importance of standardization of notes, clearances, tolerances, and other data listed on drawings is emphasised. In addition, threaded parts, gear tooth form, and many such items can and should be standardized, and serious consideration should be given to adoption of the metric system.

Since the Army-Navy (AN) Standards were developed primarily for aeroplanes and often do not apply to aircraft engines, a new set of standards must be developed for parts used on engines only.

The twenty odd gauging systems used to-day should be eliminated and only one system used, based on a decimal system. The number and letter drill sizes should be replaced by sizes based on a decimal system. It has been estimated by a firm using copper, brass and aluminium, that the saving for this firm alone would be over $1,000,000 a year if a uniform gauge system was used.

The money spent on standardization will pay dividends beyond imagination, so it is recommended that the management of engine and aeroplane companies encourage their men to serve on S.A.E. committees because, without the management's support, the work cannot be done satisfactorily.

Design and Construction of the Aero Engine Supercharger. (W. Von der Neall and H. Pfan, Z.V.D.I., Vol. 85, No. 37-38, 20/9/41, pp. 763-773.) (95/36 Germany.)

Amongst the features of special interest discussed by the author may be mentioned:—

(1). Relationship between tip speed and compression ratio at maximum efficiency, based on 313 measurements covering various designs of single-stage centrifugal blowers. It appears that tip speed of the order of 325 m. sec. are required for compensation at 20,000 feet.

(2). Effect of number of blades on efficiency. Experiments were carried out with 1-24 radial blades and with subsidiary short blades placed at the periphery of the semi-shrouded wheel. These subsidiary blades varied between 48 and 120 in number, the main radial blades being kept at 12 for these experiments. Whilst an increase in the number of blades generally leads to an increase in compression ratio, the compression efficiency suffers due to increased friction losses. It appears that 6-8 radial blades give the best all-round results, when other factors such as throttling at intake and ease of manufacture are taken into consideration.

(3). Effect of entry and exit vanes. Although such vanes may lead to improvements under certain operative conditions, they may have a deleterious effect if the running condition departs widely from the designed value. For this reason vaneless diffusors are recommended, since they facilitate installation and improve stability of operation.

Reference is made to the Planiol supercharger which is fitted with three sets of entry vanes. The increase in axial length and vulnerability of such a rotor, quite apart from manufacturing difficulties, is considered to outweigh any possible improved efficiency.

(4). Effect of altitude conditions on supercharger performance. The author considers it essential that supercharger tests be carried out at entry temperatures corresponding to those at operative heights. Altitude performance estimates from tests at normal temperatures may be seriously at fault. Compression ratio and efficiency may either increase or decrease compared with ground temperature performance, a decrease being most commonly observed. A satisfactory explanation of this behaviour has not yet been found.

The Elements of Pendulum Dampers. (T. S. Williams and R. W. Zdanovich, Proc. I. Mech. E., Vol. 143 (1940), No. 3, p. 182, and Vol. 144 (1941), p. 217.) (Discussion.) (95/37 Great Britain.)

The dynamics of a Rotating Pendulum Detuner has been treated in a completely general way, all principal known types being included. A new and practical method of considering the effects of a Pendulum Detuner when fixed at any point in the engine system has been developed showing that a Detuner of the type described virtually behaves as a simple fly-wheel whose moment of inertia can be varied at will to possess practically any value lying between the limits of plus and minus infinity, consequently its action results in an alteration or displacement of the critical speeds at which the harmonic orders occur. The effects of a Detuner on harmonic orders other than the design ones are also fully considered.

A convenient practical method is outlined for arriving at the best design of a Detuner, irrespectively of its location or position in the engine or engine transmission system. This method successfully overcomes the numerous

difficulties which were experienced by all the early designers and which were due to incomplete understanding of the general principles governing the behaviour of the Detuners. The method outlined also enables the designer to adopt easy machining tolerances for the various component parts thereby allowing for the effects of wear, distortion, thermal exapnsion, etc.

As a practical illustration a brief account is given of experimental work which was undertaken to test the behaviour of a well-known engine with a Detuner fitted at the fly-wheel. This position has been chosen as being the least obvious of all for the successful application of a Detuner. A further example is given of the application of a Detuner to a six-cylinder in-line engine. Both examples clearly illustrate the very precise agreement in all cases between experimental and calculated results.

The discussion on the Paper (Proceedings, Vol. 144, pp. 217/230) is of interest, since most of the British experts on torsional vibrations contributed. Whilst there appeared general agreement with the treatment, doubt was expressed in some quarters as to the extent slipping of the rollers can be prevented in practice. Some slipping is bound to occur if the angle of swing is large and fine tuning must become impossible if the relative amounts of slipping and rolling change.

A parallel treatment dealing with the suppression of longitudinal or axial vibrations of crankshafts etc. is discussed in the author's reply to the contributions. The possibilities of adopting various curved tracks for the suspension of pendulums, *i.e.* elliptical, hyperbolic, parabolic etc., in place of the customary circular ones, are also touched upon.

A convenient method for obtaining reliable results with a Geiger torsiograph is outlined together with some reproductions of actual records of torsional vibrations.

Special forms of pendulums and a note on the estimation of angular amplitudes are discussed in Appendices. A bibliography and a short list of the most important Patent Specifications relating to Rotating Pendulum Detuners are also included.

In the bibliography, a Paper by A. Stieglitz on "The effect of Pendular Masses on Torsional Vibrations" (published in the Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 164/178) has been omitted. This Paper, available as M.A.P. Translation No. 1012, deals with the fundamental characteristics of pendular masses on shafts, and the general conclusions are in agreement with those of the present authors. Stieglitz was careful to point out that the pendular masses act as detuners and not dampers.

A.S.T.M. Knock Rating of Aircraft Fuels. (Engineering, Vol. 152, No. 3,949, 19/9/41, p. 225.) (95/38 U.S.A.)

The test for the knock characteristics of aviation fuels, for use in aircraft engines of the spark-ignition type, differs from the method of testing the knock characteristics of motor fuels (Specification D. 357) principally in the manner in which the combustion characteristics are measured. In the new method a thermal plug is employed for comparing temperatures in the cylinder, while in the motor fuel method, knock intensity is measured by a bouncing pin and knock-meter. The term, knock characteristics, however, has been retained on account of is widespread use, even though knock intensity is not actually measured. The A.S.T.M. knock value of an aviation fuel is given as the whole number nearest to the percentage, by volume, of iso-octane 2, 2, 4-trimethylpentane) in a blend of iso-octane and normal heptane which the fuel matches, in knock characteristics, when compared by the prescribed method. It is emphasised that these specifications do not constitute a definition of aviation spirit; neither do they include all types of fuel satisfactory for spark-ignition aero-engines. Certain equipment or conditions of use may require fuels having special characteristics. Three grades of aviation spirit, however, are provided for. These vary chiefly in the matter of knock value and the grades are

designated by their respective A.S.T.M. aviation-spirit knock values, namely Grade 73, Grade 91, and Grade 100.

Lubrication of Severe Duty Engines (Diesels). (J. G. McNab and others, J.S.A.E., Vol. 49, No. 2, Aug., 1941, pp. 309-325.) (95/40 U.S.A.)

This Paper points out differences in diesel and petrol engine design and operation which result in significant differences in heat flow which may, in some cases, cause emphasis to be put on such problems as ring-sticking, wear, and piston scuffing, and in others, on sludge formation, varnish, coking, and so on.

Naphthenic and paraffinic oils of 40 and 100 viscosity index, respectively, to which have been added small amounts of a detergent-dispersal-inhibitor type additive developed by the Esso Laboratories, have been subjected to extensive laboratory and field tests and have been found to meet the most severe requirements of heavy-duty diesel service in modern transportation and industry. Results of some of these tests were compared with results of similar tests on typical naphthenic and paraffinic mineral oils commonly used for diesel lubrication under moderate conditions of speed, load, and temperature, where extreme detergency and oxidation stability are not required, on another detergent-disperser-inhibitor blend in a naphthenic base oil and on a commercial inhibited oil of the paraffinic type used in diesels requiring extreme oxidation stability but only a little detergency.

The research forming the basis of this Paper was carried out principally on three of the better-known makes of diesel engines, selected because they represented three rather distinct types of engine design and because each manifested certain of the characteristic lubrication problems which, considered together, included practically all of those peculiar to the diesel engine.

The Present Status of Combustion Research. (E. F. Fiok, J.S.A.E., Vol. 49, No. 2, Aug., 1941, pp. 332-338.) (95/41 U.S.A.)

A number of the more important contributions made recently to our knowledge of the process of combustion in the engine cylinder are reviewed briefly in this Paper.

Of the possible lines of attack which promise to lead to further improvements in the control of gaseous combustion as a source of power, the following are stressed:

1. Finding new mixtures which are inherently more powerful or more economical;
2. Finding new methods of altering the mass rate of burning, the completeness of combustion and, hence also, the rate of increase in pressure;
3. Preventing pre-ignition in spark-ignition engines and facilitating ignition in compression ignition engines;
4. Suppressing detonation.

The need for an increasing amount of combustion research and the desirability for careful co-ordination are demonstrated by an examination of progress to date.

Electrolytical Method for the Determination of the Lead Tetraethyl Content of a Fuel. ((Squeo Ignazio and Cianetti Elvio, Atti di Guidonia, No. 41, 20/1/41.) (95/42 Italy.)

A description is given of an improved method for the determination of the lead tetraethyl content of "ethylated" petrols and anti-knock mixtures, based on the electrolysis of lead nitrate, obtained either by precipitating the lead from the "ethylated" petrol with a solution of bromium in carbon tetrachloride and subsequently extracting it with nitric acid, or by extracting it with hydrochloric acid and transforming the chloride into nitrate. The most suitable conditions for such electrolyses are investigated; it is shown that the electrolytic

method is quicker and quite as accurate as the methods of precipitation hitherto practised. Finally, it is shown that the more suitable application of the method is that of combining lead tetraethyl with hydrochloric acid.

An Instrument for Measuring the Ignition Quality of Diesel Fuels. (W. H. Browne, J.S.A.E., Vol. 48, No. 4, April, 1941, pp. 148-153.) (95/43 U.S.A.)

This Paper is a report of the work done on the development of the cetane valve, an instrument used for the measurement of the cetane ratings of diesel fuels by throttling the intake air of a one-cylinder test engine. The author traces the history of the valve from its conception at the time of rating diesel fuels for altitude work to the present design, which has been used very successfully on a $5\frac{3}{4}$ by 8 inch engine, a $3\frac{3}{4}$ by 5 inch engine, and is being adapted to the CFR test engine.

Ratings made with the instrument, consisting of both reference blends and commercial fuels, are compared with results obtained by the coincident flash (CFR ignition lag) method. The advantages of the cetane valve as enumerated by the author are:

1. Simplicity of instrument and method;
2. Ease and quickness of operation;
3. Reproducibility and accuracy of results; and
4. Adaptability to engines of various strokes and bores.

A 13-year Improvement in Mixture Ratios. (W. G. Lovell and others, J.S.A.E., Vol. 48, No. 4, April, 1941, pp. 160-164.) (95/44 U.S.A.)

Between 1927 and 1940 there has been a considerable improvement in the direction of leaner air-fuel mixtures used in representative cars, amounting to an average of about two ratios at road load, equivalent to a saving of about 18 per cent. in fuel consumption. These data also suggest that there is a possibility of still further gains.

The air-fuel ratios used in automobiles represent the engineering compromise that must be made between the relatively lean mixtures which are desirable from the standpoint of economy of fuel, and the richer ones which are necessary because of inherent imperfections in commercial induction systems.

Comparisons of mixtures used by the cars tested in the three years are given on graphs showing average and range of air-fuel ratios plotted against miles per hour at road load and full load, and per cent. of energy loss plotted against miles per hour at road and full load.

Crankcase Oils for Heavy Duty Service. (H. R. Wilf, J.S.A.E., Vol. 48, No. 4, April, 1941, pp. 128-137.) (95/45 U.S.A.)

This Paper presents the results of road and dynamometer tests made to evaluate crankcase oils; appraises the effect of operating conditions; and reviews the causes and cures of failure of copper-lead bearings in heavy-duty service.

During the past year attention has been focused on the failure of copper-lead bearings in heavy-duty service. These failures may be classified as loss of lead due to the corrosive effect of the lubricant, and mechanical failures due to fatigue. Corrosion and fatigue are greatly accelerated by an increase in bearing pressure; consequently, tests made in full-size multi-cylinder engines more closely approximate service conditions than miniature single-cylinder engine tests or laboratory bearing corrosion tests.

Loss of lead may be caused by the solvent action of acidic products formed on oxidation of the base oil. The oxidation of the base oil may be greatly accelerated by the catalytic effect of metallic soaps used as detergents.

Metallic compounds other than metallic soaps, which either do not break down under the conditions existing in the high-pressure bearing areas or do not form free

acids or acidic compounds on decomposition, are available as detergent compounds. This type of metallic detergent compound does not cause bearing corrosion.

Effect of Quenching Rate on Susceptibility to the Intercrystalline Corrosion of Heat Treated 24S Aluminium Alloy Sheet. (H. L. Logan, J. of Research Nat. Bureau of Stands., Vol. 26, No. 4, April, 1941, pp. 321-329.) (95/46 U.S.A.)

The effect of the quenching rate of the 24S (aircraft) aluminium alloy upon its behaviour in an accelerated corroding solution ($NaCl + H_2O_2 + H_2O$) was determined. Specimen cooled from a temperature above 400°C. at a rate in excess of 815° to 1,110°C./sec. (increasing with increasing copper content of the alloy) were susceptible only to the pitting type of corrosion. Specimen cooled at a rate less than 300° to 400°C./sec. (increasing with increasing copper content) and specimens cooled slowly to a temperature below 400°C. before quenching were subject to severe intercrystalline corrosion. For cooling rates between the above ranges there was a gradual change from one type of corrosion to the other.

Cooling rates were determined by means of a thermocouple and an Einthoven string galvanometer.

Influence of Stress on the Corrosion Pitting of Aluminium Bronze and Monel Metal in Water. (D. J. McAdam and G. W. Geil, Bur. Stan. J. Res., Vol. 26, No. 2, Feb., 1941, pp. 135-139.) (95/47 U.S.A.)

Cyclic stress tends to increase the size and sharpness of corrosion pits in aluminium bronze and monel metal and thus tends to increase the rate of lowering of the fatigue limit by corrosion. The form of corrosion pits in aluminium bronze is affected by the duplex microstructure. Pits in monel metal are not appreciably influenced by the microstructure. Curves of decrease of the fatigue limit, and constant-damage diagrams derived from these curves, are very different from those obtained with steels. These differences may be attributed to the fact that the rate of corrosion of aluminium bronze and monel metal, unlike that of steel, is anodically controlled. Steady stress tends to increase the rate of corrosion pitting of aluminium bronze but has little apparent effect on monel metal.

Phosphate Coatings Facilitate the Cold Working of Metals. (H. Faber and H. Kopp, Korrosion and Metallschutz, Vol. 17, No. 6, June, 1941, pp. 211-214.) (95/48 Germany.)

During the cold work of metal (such as the drawing of tubes and rods, and the deep drawing of containers), considerable friction is necessarily set up between the surface of the material and the die. In order to reduce wear of the die and the seizure of the material, it has been customary to use certain oils and fats as lubricants. The difficulty is to ensure adhesion of the lubricant under these arduous conditions, and although it is usual to roughen the surface of the material between the various stages of the process, the oil film will tear unless the rate of working is carefully adjusted. It has been discovered recently by Singer that the retention of the lubricant can be vastly improved if the material is coated with a phosphate layer prior to drawing. A zinc phosphate deposit by the Bonder process has been found specially suitable and is covered by the German Patent 673,405. The thickness of the deposit will depend on the degree of deformation required. In the case of tubes, one coating will generally last up to five consecutive drawings. In many cases it is thus possible to reach the final dimensions without a reheating of the material. Examples are given of electrically-welded steel tubes (S.M. Steel of 35/40 kg./mm.^{2} tensile) which were drawn in this way in five stages from an original diameter of 26 mm. and 1.2 mm. thickness to 16 mm. diameter and .6 mm. thickness. This implies

a reduction in area of cross-section of 69 per cent. Even more spectacular results were obtained with Cr.-Mo. steel (cross-section reduced by over 80 per cent. in five stages without reheating).

The process has also been applied successfully to pressure vessels, wire drawing, up-setting of screw heads, etc. and, in the author's opinion, constitutes one of the outstanding discoveries of recent times.

Phosphate Coatings as Running-in Layers for Piston Rings. (F. Bremer, Korrosion und Metallschutz, Vol. 17, No. 6, June, 1941, pp. 208-209.) (95/49 Germany.)

Modern developments in high-duty engines have necessitated the use of piston rings made of wear-resisting material. The running-in of such rings is necessarily a lengthy process and many attempts have been made to shorten the time required, either by putting up the contact pressure (stepped or chamfered rings) by the provision of soft metal inserts in the ring surface or by covering the latter with a deposit of tin, copper or cadmium. Whilst the latter process has met with a certain amount of success, its general application is not recommended by the author since it is fairly complicated and the metals required for the deposit are not produced in Germany. Recent experiments have shown that better results can be obtained in a simpler manner by applying phosphate coatings to the ring surface. The Abrament Process (I.G. Farbenindustrie) is used, the deposit consisting of a mixture of manganese and iron phosphates or zinc and iron phosphates, depending on the nature of the piston ring material. The time of treatment depends on the temperature and composition of the bath, and varies between ten minutes and one hour. Experience has shown that the deposit should consist mainly of fine crystals, uniformly distributed. A few coarse crystals inside this matrix are not harmful. If, however, the whole deposit is coarsely crystalline, the coat loses its value and may even increase the running-in time required. The great advantage of the phosphate layers lies in the fact that the final bearing surface is free from distortion or displacement of material. If the ring surface is finely machined before the coat is applied, the gas seal is almost perfect from the start so that the engine can be operated normally even before the running-in process is completed.

Phosphate coatings are oil absorbent and in an emergency will run dry for an appreciable time without seizing. The danger of local high-pressure zones leading to partial seizure during normal operation is thus much reduced.

In conclusion the author states that a further deposit of graphite on top of the phosphate coating may prove beneficial.

Metal Spraying with an Electric Arc Gun. (J. Am. Soc. Nav. Engs., Vol. 53, No. 3, Aug., 1941, pp. 688-689.) (95/50 U.S.A.)

A new method of metal spraying has been developed by Dr. M. U. Schoop of Switzerland, originator of the metal-spraying process, which makes use of a spray gun utilizing an electric arc to melt the metal to be deposited. Hitherto, the metal-spraying process has depended upon a gas flame of some kind to melt the metal before being deposited on the base surface.

The new Schoop process consists essentially of short-circuiting two conducting wires which pass through the spray gun, atomizing each drop of metal melted by the resulting arc, and projecting the atomized metal by means of a compressed air blast on the surface to be metallized. A small luminous arc is formed at the breaking point, insuring the continued melting of the wires, which are constantly being fed forward by means of a turbine. Although the compressed air blast directed through the arc may be fed into the gun at pressures ranging from 60 to 120 pounds per square inch, the arc is reported to be entirely stable.

The new process of metal spraying is claimed to be highly economical and efficient. It is said that about twenty-two pounds of carbon steel or stainless

steel wire can be sprayed during each hour of operation. In many cases, the pre-treatment of the surfaces by sand-blasting heretofore required, can be dispensed with because of the increased strength of bond secured by this method of deposition. Thus, if a glass plate is electro-metallized with aluminium or steel by this process, and an attempt is made to remove the deposited metal, a layer or " skin " of glass will also be torn off. It appears that owing to the electric arc, the temperature of the sprayed metal particles is so high that they melt into the surface against which they are propelled, rather than becoming merely a surface layer.

Arc Welding without Residual Stresses. (R. E. Spaulding, J. Am. Soc. Nav. Engs., Vol. 53, No. 3, Aug., 1941, pp. 675-679.) (95/51 U.S.A.)

The process recommended consists in pressing or light-hammering the weld area while it is cooling (vibratory pressure is best; steady pressure only if welding process is continuous). This added pressure (applied at right angles to the axis of the weld) can usually be best obtained by the use of a light pneumatic or electric hammer having a tool face adapted to the desired size and contour of the weld. If applied at the right time, that is while the yield strength of the hot weld is relatively low, only a small amount of effort is needed and all shrinkage tendency is found to have been eliminated.

The new method must not be confused with so-called " peaning " or hammering of the weld area after it has cooled to such an extent that the elastic limit or yield strength of the area has again approximated that of the original metal. Nor should it be compared to re-heating of the weld area, with or without treatment while heated, since no heat produced by a flame can even approximate the same relative heat penetration with corresponding surface intensity of that resulting from an electric arc. In both of these latter methods counter-balancing locked-in stresses may be introduced which will overcome warpage but the welded assembly is nevertheless still subject to high internal stresses, and often the physical structure of the metal is disturbed and weakened.

Method of Selecting Ball and Roller Bearings—II. (Ungar, Machinist, 20/9/41, pp. 214-215.) (95/52 Great Britain.)

In this article, the author shows the method of selection of a bearing for the spindle head of a typical plain milling machine. A minimum life expectancy of 10,000 hours is assumed and also that the motor is always operating at its maximum horse-power and speed. Results from two equations previously recorded by the author are tabulated and from these suitable bearings for a portable electric saw are chosen.

(Abstract supplied by Research Dept., Met. Vick.)

A New Chromising Process. (Rudorff, Met. Ind., 26/9/41, pp. 194-195.) (95/53 Great Britain.)

Although there are several ways in which the high corrosion resistance of chromium can be utilized for the protection of iron and steel, the most widely known, chromium plating, requires an intercoating between the steel surface and the chromium layer. The author states that much greater wear resistance and service life can be obtained by resorting to chromium impregnation, the process of which is described, in which an integral surface layer is formed by a diffusion process employing an atmosphere containing chromous chloride.

(Abstract supplied by Research Dept., Met. Vick.)

Metal Coating of Plastics. (B.I. Plastics and Moulded Product, Sept., 1941, p. 106.) (95/55 Great Britain.)

It is claimed that in the process of coating plastics with zinc, aluminium, copper or tin, the metal particles join with the synthetic resin particles and therefore

strengthen the surface of the moulded article. The process can also be applied to cast resin and to laminated and cellulose products. Results are given of test carried out to compare the electro-magnetic screening properties of the metal film with tinfoil of the same dimensions.

(Abstract supplied by Research Dept., Met. Vick.)

Avoiding Galvanic Corrosion in Light Alloy Products. (Taylor, Metallurgia, June, 1941, pp. 43-46 and 66.) (95/56 Great Britain.)

It is stated that many failures of metals and alloys in service are due to galvanic corrosion, and in this article means by which this form of corrosion proceeds are discussed. Some considerations in the design of composite components are given with the object of avoiding or reducing galvanic action and some principles are discussed, the observance of which is claimed to limit the number of failures from this cause.

(Abstract supplied by Research Dept., Met. Vick.)

The Protection of Duralumin in Aircraft Structures. (A. Iacoboni, Atti di Guidonia, Nos. 45-47, 20/3/41.) (95/57 Italy.)

In a preliminary discussion it is shown that in order to assess the real protective efficiency of a given coating and to obtain a guide in making a suitable selection, in addition to corrosion tests under conditions which approach the actual working conditions as closely as possible, further investigations and tests are necessary in order to ascertain the numerous other characteristics of the protective layer. A complete series of laboratory experiments have been carried out and from the results it has been possible to establish the system which, in each case, is the most suitable for the protection of duralumin in aircraft constructions. At the same time, with the different processes of protection under investigation, the causes of their particular behaviour are revealed and the different manner and form in which the phenomenon of corrosion takes place under the different conditions and with different protective systems are indicated.

The Circular Cylinder with a Band of Uniform Pressure on a Finite Length of the Surface. (M. V. Barton, J. App. Mech., Vol. 8, No. 3, Sept., 1941, pp. 97-104.) (95/58 U.S.A.)

The solution to the fundamental problem of a cylinder with a uniform pressure over one-half its length and a uniform tension on the other half is found by using the Papcovitch-Neuber solution to the general equations. In this Paper, the results, given analytically in terms of infinite-series expressions, are exhibited as curves giving a complete picture of the stress and deformation. The case of a cylinder with a band of uniform pressure of any length, with the exception of very small ones, is then solved by the method superposition. The stresses and displacements are evaluated for the special cases of a cylinder with a uniform pressure load of 1 diameter and $\frac{1}{2}$ diameter in length. The problem of cylinder heated over one half its length is solved by the same means.

The Effect of Foundation Stiffness on the Resonant Frequencies of Rotating Machines. (E. H. Hull, J. App. Mech., Vol. 8, No. 3, Sept., 1941, pp. 121-129.) (95/59 U.S.A.)

The work described in this Paper was carried out in an attempt to clarify the problem of determining the effects of elastic foundations under rotating machines on the resonant speeds of those machines. Non-rotating models were used as a medium for studying this problem for reasons of expediency in construction, manipulation and measurement. These models consisted of a " rotor " mounted in " bearings " from a rigid stator which in turn was supported through a foundation, the stiffness of which could be varied. The behaviour of uniform rods and models of turbo-driven alternator rotors was studied in this apparatus. Results

showed a wide variation of certain resonant frequencies of the model system with foundation stiffness, emphasizing the need for careful consideration of the effect of this factor on the resonant speeds of full-sized machines when run on their permanent foundations.

Actions of Deep Beams Under Combined Vertical, Lateral and Torsional Loads. (C. O. Dohrenwend, J. App. Mech., Vol. 8, No. 3, Sept., 1941, pp. 130-134.) (95/60 U.S.A.)

This Paper is devoted to a discussion of the behaviour of beams when the primary load acts at the same time as the secondary lateral and torsional loads. Beam loading of this type occurs in the case of shop travelling cranes, measurements indicating that the lateral and torsional loads are much smaller than the primary vertical load. The author considers the problem of the " deep beam " in which the moment of inertia of the cross-section about the horizontal axis is much greater than about the vertical axis. The solution is achieved by determining the equation of twist in the beam and the moment or load where small increases of their values cause large increases in the values of angle of twist.

Use of Hardenability Tests for Selection and Specification of Automatic Steels. (A. L. Boegehold, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 266-276.) (95/63 U.S.A.)

The fundamental relationship between cooling rate during quenching and hardness produced in steel is pointed out. The requirements for a hardenability test bar for determining this relationship for a wide variety of section sizes and steels are given. Some of the methods that have been suggested for testing hardenability are discussed briefly, pointing out that the end-quench specimen is best suited for obtaining this fundamental relationship beween hardness and cooling rate.

A method of interpreting hardenability information obtained from various hardenability tests in terms of hardness cooling rate curves is explained. This translation of hardenability information rate curve permits the use of these various test bars for the purpose of predicting hardness in complicated shaped articles. The H-CR curve is the abbreviated name taken for convenience in referring to the hardness-cooling rate curve.

Determination of Hardenability on Small Sizes. (F. E. McCleary and R. Wuerfel, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 276-278.) (95/64 U.S.A.)

Limitations of the two general methods available for determining hardenability in steel, are that the test piece may not have a sufficient cross-section in which to develop the desired series of cooling rates, and that a special test piece (known as the L-type) must be machined for steels of low hardenability. The method using the Wuerfel bomb described in this Paper is directed primarily toward removal of these two limitations.

Stated in terms of the critical diameter, the results of the method are reproducible within $\frac{1}{8}$ in.

Determination of Specific Hardenability of Shallow Hardening Steels. (O. V. Greene and C. B. Post, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 278-283.) (95/65 U.S.A.)

A taper test specimen having a taper of 1 in. in 5 in. of length, $\frac{1}{4}$ in. in diameter at one end and 1.1/4 in. in diameter at the other end, is proposed as a test for measuring the specific hardenability of shallow-hardening steels. The hardened taper test specimens are split and Rockwell hardnesses obtained along the central axis of test specimen, or the central section may be etched

lightly to bring out the relative colours of case and core. This taper test specimen has been correlated with the Jominy-Boegehold " L " bar. This enables the rate of cooling at any point along the central axis of the taper test specimen to be expressed in terms of deg. F. per sec. at 1,300 F.

The taper test specimen has also been correlated with the work of Grossmann and his associates concerning critical bar diameters and severity of quench. It is shown experimentally that this degree of taper is small enough so that the taper test specimen behaves within experimental error like a series of round bars whose diameters are given by twice the perpendicular distance from the surface of the taper test specimen to any point along the centre axis.

A correlation is shown between the Shepherd disc hardenability Nos. 10 to 16 inclusive and the critical cooling velocity in deg. F. per sec. of 1,300 F. (as determined from the cooling rates published for the Jominy-Boegehold Type " L " bar) and critical bar diameters at a severity of quench of $H=4.5$, or the " ideal critical bar diameters " for $H=\infty$.

Correlation Between Jominy Test and Quenched Round Bars. (M. Asimow and others, J.S.A.E., Vol. 49, No. 1, July, 1941, pp. 283-293.) (95/66 U.S.A.)

A number of different tests have been developed for ascertaining the hardenability of steel, that is its susceptibility to hardening by quenching. Although each of these different tests may be suited particularly to a specific problem, it would be useful to know how to interpret one test in terms of another. The present Paper suggests a manner of correlating the extent of hardening in the Jominy-Boegehold end-quench test with the extent of hardening in quenched round bars.

For any particular steel, the extent to which it hardens when quenched varies with the cooling rate (cooling time) in the quench. That is, if cooled rapidly enough it will become hard and, if cooled slowly it will be soft, so that for each steel a series of hardness may be found experimentally corresponding to a series of cooling times. Different cooling times occur along the length of a Jominy bar, and various cooling times are also found at various positions in different sizes of quenched bars, quenched with various severities of quench.

It therefore becomes possible to predict from the results of a Jominy test what the hardness distribution will be on the cross-section of a quenched round bar when quenched with a known severity of quench.

Oblique Incidence Radio Transmission and the Lorentz Polarization Term. (N. Smith, Bur. Stan. J. Res., Vol. 26, No. 2, Feb., 1941, pp. 105-116.) (95/67 U.S.A.)

The force on an electron in an ionized medium may be written $E+4\pi aP$ per unit charge, where E is the electric force, P the polarization of the medium, and a constant which is zero on the Sellmeyer theory and may have a value of $1/3$ on the Lorentz theory. A well defined distinction exists between maximum usable frequencies for ionospheric radio transmission calculated on the basis of the two theories. This Paper describes a type of experiment for measuring maximum usable frequencies and comparing them with calculated values. The results indicate that a is probably zero, at least in these experiments. There is also described a step-by-step method of solving the virtual-height integral equation, necessary in much theoretical work concerning the ionosphere.

Diffraction Theory of Electromagnetic Waves. (J. A. Stretton and L. S. Chu, Physical Review, Vol. 56, July, 1939, pp. 99-107.) (95/68 U.S.A.)

It has been shown by Larniov, Kottler and others that the classical method of calculating diffraction from the Kirchhoff formula in terms of the scalar light functions cannot be applied directly to the electro-magnetic field since neither the Vector character of the field nor the effect of charges along the contour of

the opening are taken into account. The field equations are integrated directly by the authors by means of a Vector analogue of Green's theorem. The results are applied to calculating the diffraction of electro-magnetic waves from a rectangular slit in a screen of infinite conductivity. The results are compared with an exact solution of the two-dimensional problem published in Phy. Rev. 54, 895 (1938) by Morse & Rubinstein.

The distributions given by these authors agree very satisfactorily with the equatorial solution given in the present Paper. It appears therefore that the simple equations given by Stretton & Chu can be applied to diffraction phenomena with confidence. In the case of radiations from hollow tubes and horns, an extension to take account of the internal reflected wave (by methods similar to those applied in acoustics) should not prove difficult.

The Investigation of Rapidly Changing Mechanised Stresses with the Cathode Ray Oscillograph. (S. L. de Bruin, Philips Technical Review, Vol. 5, No. 1, Jan., 1940, pp. 26-28.) (95/69 Holland.)

The method consists in attaching a resistance strip to the structural element under investigation. The strip is made of insulating material, 50 mm. long, 8 mm. wide, and .3 mm. thick. The ends are made conducting by means of a deposit of silver and a line is drawn on the strip with a drawing pen using very finely divided carbon powder suspended in a liquid binder. The binder is dried by heating and the resultant element has a resistance of about 10,000 ω. It is next cemented to the surface under examination by means of celluloid lacquer, dried under pressure. The electrical resistance of the strip changes with its longitudinal dimension and is recorded by means of a cathode ray oscillograph, which measures the effective voltage across the strip, the latter being in series with a high resistance and battery. A valve amplifier built into the oscillograph unit gives an effective amplification of about 1,500. Direct calibration has shown that the relationshop between specific extension λ and specific resistance ρ of the strip is practically linear for extensions up to .03 per cent. Over this range, $\lambda/\rho = 15$ app.

The Laryngophone. (J. De Boer and K. De Boer, Philips Technical Review, Vol. 5, No. 1, Jan., 1940, pp. 6-14.) (95/70 Holland.)

In telephoning it is possible to use as excitation agent the mechanical vibrations of the speaker's throat instead of the air vibrations which occur in front of the mouth of the speaker. This method makes it possible to use the telephone in places where there is so much noise that the human voice is drowned. The picking up of the throat vibrations is done with a laryngophone, the principle and several structural details of which are described in this article. Two different types have been developed: a crystal microphone in which the chief aim has been the best possible quality of reproduction, and a carbon microphone whose sensitivity can be made so great that it can be used directly in a telephone apparatus instead of the usual microphone. A consideration of the sensitivity of the laryngophone for air vibrations as well as a series of intelligibility tests show to what degree the desired purpose has been realized in the laryngophones described.

It appears that with the crystal microphone, conversation can be carried out with an intelligibility of the order of 86 per cent., the noise background having a disturbance level as high as 123 phons. With an ordinary telephone intelligilibity is zero when the speaker is surrounded by a noise level of only 90 phons.

Another application of the device is in combination with gas masks. An air microphone is quite useless in this case due to resonance in the small sealed airspace inside the mask. Moreover, the microphone can in this case be passed from one speaker to another without having to open the mask.

The Effect of Silver on the Performance of Antimonial Lead Storage Batteries. (Fink, Dornblatt, Metallurgia, June, 1941, pp. 39-40.) (95/71 Great Britain.)

The results are given of an investigation into the effect of from 0.05-0.15 per cent. of silver upon the properties and performance, in storage batteries, of lead alloys containing from 4 to 12 per cent. of antimony. It is claimed that batteries with heat-treated 4 per cent. antimony, and 0.10 per cent. silver alloy grids have improved characteristics in corrosion resistance of the positive plates, ruggedness, battery life, retention of charge and low temperature rise on overcharge.

(Abstract supplied by Research Dept., Met. Vick.)

The Radiosonde. (E. T. Clark and S. A. Korff, J. Frank. Inst., Vol. 232, No. 3, Sept., 1941, pp. 217-238.) (95/72 U.S.A.)

The radiosonde, the most recently developed tool for use in the investigation of phenomena in the upper atmosphere, is described. The various merits and disadvantages of the three systems now in use for the transmission of physical data from the stratosphere are reviewed. In a discussion of present-day radiosonde technique are included descriptions of transmitters, receivers, meteorological and other observing instruments, and ballooning methods. Their application to the study of cosmic rays is given as a typical illustration of their usefulness in fields other than meteorological. A new formula for the upward velocity of the flight in terms of its free lift is developed, which shows that the observed constant rate of ascent of pilot type balloons is fortuitous, depending on a particular range of values of the Reynold's Number of the balloons.

Daytime Photo-Electric Measurement of Cloud Heights. (M. K. Laufer and L. W. Foskett, Bur. Stan. J. Res., Vol. 26, No. 4, April, 1941, pp. 331-334.) (95/73 U.S.A.)

A photo-electric detector is used in conjunction with a modulated beam of light for the measurement by triangulation of the height of clouds during the daytime. An a.c. operated mercury-arc lamp is used to obtain the modulated beam. An electronic " synchronous switch " is used to eliminate the effect of the varying background brightness of the clouds. The shot noise of the photo-tube, resulting from the relatively high brightness of clouds during the daytime, limits the detection. Dark overcast clouds at an elevation of 9,000 feet have been detected.

Methods for Determining Sound Transmission Loss in the Field. (A. London, Bur. Stan. J. Res., Vol. 26, No. 5, May, 1941, pp. 419-453.) (95/74 U.S.A.)

In the customary method of determining the transmission loss of a wall or floor partition, it is necessary to measure the difference in sound levels existing in two rooms which have the partition as a separating wall or floor. Also the ratio A_2/S, where A_2 is the total sound absorption of the receiving room and S the transmitting area of the partition, must be known. Difficulties are experienced in field measurements because of the non-uniformity of sound levels in the test rooms and an uncertain knowledge of A_2. Two new methods which eliminate these difficulties are described. In both of these methods the sound level on the quiet side is measured at the panel face, in the one method with a pressure microphone and in the other with a pressure-gradient (ribbon) microphone. In the latter method the transmission loss is independent of the value of A_2/S if the panel face has little sound-absorptive value, while in the former it is possible, in most cases, to eliminate the necessity of measuring A_2 by determining in addition the average sound level in the receiving room.

Also, the possibility of using the ribbon microphone as a radiation pick-up is indicated.

Some Factors Influencing the Performance of Diaphragm Indicators of Explosion Pressures. (F. R. Caldwell and E. F. Fiock, Bur. Stan. J. Res., Vol. 26, No. 3, March, 1941, pp. 175-196.) (95/75 U.S.A.)

Information obtained during the development and use of accurate diaphragm-type indicators of the pressures developed during explosions of gaseous mixtures in bombs is presented. Although some of the following conclusions are not original, all are supported by new experimental evidence.

It is shown that all passages and cavities on the explosion side of the diaphragm should be eliminated for highest accuracy. Although the sensitivity of the diaphragm to pressure difference must not be less than the value determined by the accuracy with which pressures are to be measured, it is important, when highest accuracy is desired, that the sensitivity shall not greatly exceed this same value so that the inertia error will not become larger than the allowable tolerance. Radial tension in the diaphragm is advantageous in reducing time lag. A blued or polished surface is preferable to one which absorbs more radiant energy. Projections around the diaphragms are without measurable effect upon the performance of the indicators.

It seems probable that, with a properly designed indicator, the measured values of explosion pressure need not deviate from the actual pressure by more than a few tenths of 1 mm. Hg.

Library—Laboratory Research. (Mech. Eng., Vol. 63, No. 5, May, 1941, pp. 381-382.) (95/76 U.S.A.)

Costly repetition of research already described completely in the literature and failure to appreciate inventions described almost verbatim in the literature; these evils will continue until the scientist gives to library research the attention it merits. Already the time has come when research programmes should provide a definite place for a new type of scientist. This scientist will devote all, or the greater part, of his time to thorough investigation of scientific literature. His research will be marked by the same thoroughness, concentration, imagination and resourcefulness exhibited by brother scientists in research laboratories. He will guide laboratory programmes from the pitfalls of prior art. He will unearth innumerable inventions now hidden in the literature, and he or his fellow scientists will check those library discoveries by laboratory tests.

A Mechanical Device for the Determination of the Differential Coefficients of a Given Curve. (P. Teofilato, Atti di Juidonia, No. 48, 10/4/41.) (95/77 Italy.)

The author reviews the practical difficulties entailed in obtaining, from a diagram, the second derivative of the function expressed by this diagram, when the latter is disturbed by oscillations. He describes a mechanical device which depends on determining the loads required to bond an elastic rod so that it lies along the curve. The required derivative (*i.e.* curvature) can be easily determined from the distribution of the bending moment.

Note on the Angular Motions of Ships. (N. Minorsky, J. App. Mech., Vol. 8, No. 3, Sept., 1941, pp. 111-120.) (95/78 U.S.A.)

The object of this Paper is to bring to the attention of mechanical engineers a number of dynamical problems encountered in the theory of the ship; to indicate briefly the form of corresponding differential equations and their solutions; to analyze the validity of underlying theoretical assumptions; and to approach in this manner a comparison of the ship's dynamics with problems commonly encountered in other fields, such as that of vibration theory.

LIST OF SELECTED TRANSLATIONS.

No. 38.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft Production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

AERO AND HYDRODYNAMICS.

TRANSLATION NUMBER AND AUTHOR.	TITLE AND JOURNAL.
1244 Hoff, W.	*Notes on the Ideal Efficiency of Air Screws.* (L.F.F., Vol. 18, No. 4, pp. 114-121.)
1246 Bolotnikov, V. ...	*Correction of the Speed Indicator at High Speeds of Flight.* (Air Fleet News, U.S.S.R., Vol. 23, No. 2, Feb., 1941, pp. 159-166.)
1257 Sieg, H.	*Propagation of Sound in the Free Atmosphere and its Dependence on Meteorological Conditions.* (El. Nachrichten Technik, Vol. 14, No. 9, Sept., 1940, pp. 193-208.)
1270 Wolf, K. ... ... Rumpf, H.	*On the Extractor Action of a Two Dimensional Spiral Air Flow.* (Z.V.D.I., Vol. 85, No. 27, 5/7/41, pp. 601-604.)
1287 Tollmien, W. ... Schafer, M. ...	*On the Theory of Wind Tunnel Turbulence.* (Z.A.M.M., Vol. 21, No. 1, Feb., 1941, pp. 1-17.)

AIRCRAFT AND ACCESSORIES.

1241 Kotelmikov, V. A....	*Longitudinal Dynamic Stability of an Aeroplane with an Automatic Pilot.* (Aeron. Eng., U.S.S.R., Vol. 15, No. 1, Jan., 1941, pp. 27-31.)
1249 Anders, K.	*Prevention of Ice Formation.* (Der Deutsche Sportflieger, Jan., 1941, p. 6.)
1256 Miram, P.	*The Influence of Atmospherics on Wireless Reception in Aircraft.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 113-114.)
1277 Margerre, K. ...	*Stresses in Reinforced Cut-outs.* (L.F.F., Vol. 18, No. 7, 19/7/41, pp. 253-261.)
1278 Puishnoff, V. S. ...	*Aircraft Manœuvrability Coefficient.* (Aeron. Eng., U.S.S.R., Vol. 14, No. 12, Dec., 1940, pp. 26-30.)
1280 Stuper, J.	*The Measuring Technique of Flight Tests.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 109-113.)
1284 Stieds, W.	*The Statics of Circular Frames Used in Aircraft Pressure Cabins.* (L.F.F., Vol. 18, No. 6, 30/6/41, pp. 214-222.)

Material and Elasticity.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND JOURNAL.
1243	Kimm, G.	*The Stability of Thin-Walled V Sections of Constant Thickness in Elastic Region.* (L.F.F., Vol. 18, No. 5, 28/4/41, pp. 155-168.)
1251	Kuch	*Home Produced Materials for Aircraft Construction.* (Johnbuch de Deutschen Luftfahrtforechung, 1937, pp. 551-572.)
1264	Romashevsky ...	*Investigation of Thin-Walled Beams with Non-Parallel Strips.* (Trans. C.A.H.1, No. 203.)
1269	Berg, S.	*Technique of Fatigue Testing.* (Z.V.D.I., Vol. 85, No. 27, 5/7/41, pp. 605-608.)
1275	Posch, T.	*An Elementary Theory on Fatigue Strength.* (Ing. Archiv., Vol. 12, No. 2, April, 1941, pp. 71-76.)

Miscellaneous.

1250	Sakharov, K. N. ...	*A Device for Joining Short Lengths of Films.* (Air Fleet News, U.S.S.R., Vol. 23, No. 3, March, 1941, pp. 263-264.)
1252	Yieweg, R. ... ... Gottwald, F. ...	*A New Method for Determining Small Friction Couples.* (Z.V.D.I., Vol. 85, No. 18, 3/4/41, pp. 417-419.)
1276	Bulgarkov, B. Y. ...	*Accumulation of Errors on Gyro Apparatus.* (Ing. Arch., Vol. 11, No. 6, Dec., 1940, pp. 461-469.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING SEPTEMBER, 1941, TOGETHER WITH LIST OF NEW TRANSLATIONS RENDERED AVAILABLE.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

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4	28744	U.S.A. ...	*Brewster SB2A-1 Dive Bomber* (*Photograph*). (Aero Digest, Vol. 31, No. 1, July, 1941, p. 104.)
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11	28782	Great Britain	*Handley Page Halifax Bomber* (*Photographs*). (Aeroplane, Vol. 61, No. 1,583, 26/9/41, pp. 338-339.)
12	28790	Great Britain	*Assembling the Beaufighter*. (B. Foster, Airc. Prod., Vol. 111, No. 36, Oct., 1941, pp. 347-353.)
13	28795	U.S.A. ...	*Originality in the Bell Airacobra*. (Airc. Prod., Vol. 111, No. 36, Oct, 1941, pp. 364-367.)

14	28796	Great Britain	*Wooden Wings in Manufacture for Miles Trainer Aircraft.* (Airc. Prod., Vol. 111, No. 36, Oct., 1941, pp. 373-375.)
15	28799	Great Britain	*Hawker Hurricane II.* (Aeroplane, Vol. 61, No. 1,584, 3/10/41, p. 359.)
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19	28806	Great Britain	*The Ideal Trainer with Special Reference to the Side-by-Side Cabin Type.* (Flight, Vol. 40, No. 1,710, 2/10/41, p. f-216.)
20	28808	Germany ...	*Focke Wulf 189 Observation Plane.* (Flight, Vol. 40, No. 1,710, 2/10/41, p. 222.)
22	28830	U.S.A. ...	*Curtiss P40D Fighter (Photograph).* (U.S. Air Services, Vol. 26, No. 8, Aug., 1941, p. 29.)
23	28831	U.S.A. ...	*Curtiss S.N.C.-1 Two Place Trainer (Photograph).* (U.S. Air Services, Vol. 26, No. 8, Aug., 1941, p. 30.)
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26	28856	U.S.A. ...	*Twin Tail Booms of Lockheed Lightning and F.W. 189.* (Flight, Vol. 40, No. 1,711, 9/10/41, p. 235.)
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33	28875	Germany ...	*The Armament of British Military Aircraft (Based on an Examination of Captured Material).* (J. Beseler, Luftwissen, Vol. 8, No. 8, Aug., 1941, pp. 237-243.)
34	28877	U.S.S.R. ...	*Photographs and Short Description of Front Line Russian Military Aircraft.* (Luftwissen, Vol. 8, No. 8, Aug., 1941, pp. 244-245.)

35 28885 Germany ... *New German Types on the Russian Front (Do. 29 and He. 177).* (Flight, Vol. 40, No. 1,712, 16/10/41, p. 258.)

36 28891 Great Britain *Heating Air Raid Shelters.* (Engineering, Vol. 152, No. 3,952, 10 Oct., 1941, p. 292.)

37 28913 Germany ... *Series Production of Ju. 88.* (Der Flieger, Vol. 20, No. 8, Aug., 1941, pp. 254-258.)

38 28914 U.S.S.R. ... *Types of Russian Military Aircraft.* (Der Flieger, Vol. 20, No. 8, Aug., 1941, pp. 259-261.)

39 28916 U.S.S.R. ... *Stormovik Dive Bomber (Photograph).* (Aeroplane, Vol. 61, No. 1,586, 17/10/41, p. 413.)

40 28917 Great Britain *Hawker Hurricane, IIc.* (Aeroplane, Vol. 61, No. 1,586, 17/10/41, pp. 419-421.)

41 28918 Great Britain *Unburstable Petrol and Water Container for Dropping Supplies.* (Aeroplane, Vol. 61, No. 1,586, 17/10/41, p. 428.)

42 28919 Germany ... *German Aeroplanes in Service (VIII) (Fieseler and Focke Wulf Series).* (Aeroplane, Vol. 61, No. 1,586, 17/10/41, p. 431.)

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45 28925 U.S.A. ... *To-day's Machine Tools, Machinery and Mechanised War.* (R. E. W. Harrison, J. Am. Soc. Nav. Engs., Vol. 53, No. 3, Aug., 1941, pp. 533-547.)

46 28942 U.S.A. ... *Use of Gliders for Carrying Fuel and Assisted Take-off.* (American Aviation, Vol. 5, No. 7, 1st Sept., 1941, p. 6.)

48 28961 Germany ... *Relation between Rotary and Translatory Motion of the Shell Moving Along the Gun Barrel.* (M. Erdres, Z.G.S.S., Vol. 36, No. 9, Sept., 1941, pp. 190-192.)

49 28966 Great Britain *The Whitley V (Part II, Assembly of Fuselage).* (B. Foster, Airc. Prod., Vol. III, No. 33, July, 1941, pp. 234-241.)

50 28969 Great Britain *Bristol Beaufort.* (Airc. Prod., Vol. III, No. 33, July, 1941, pp. 254-256.)

51 28994 Canada ... *Ferrying Fighter Planes from Canada to England.* (Canadian Aviation, Vol. 14, No. 6, June, 1941, pp. 29-30.)

52 28996 Canada ... *Examination of Me. 110 by Vultee Experts.* (Canadian Aviation, Vol. 14, No. 6, June, 1941, pp. 32-34 and 42.)

53 28997 Canada ... *Vultee Vengeance Dive Bomber.* (Canadian Aviation, Vol. 14, No. 6, June, 1941, p. 72.)

54 28998 Canada ... *Gliders for Invasion.* (Canadian Aviation, Vol. 14, No. 6, June, 1941, pp. 35 and 44.)

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56 29024 U.S.A. ... *Fokker G.1 Twin Tail Fighter.* (Aviation, Vol. 40, No. 7, July, 1941, p. 61.)

57 29026 U.S.A. ... *Machine Gun Mounting in Bottom of Fuselage of Northrop N-3 Patrol Bomber.* (Aviation, Vol. 40, No. 7, July, 1941, p. 65.)

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64 29041 U.S.A. ... *Eleven Gliders Towed by Russian Twin-Engined Bomber MBR-2 (Photograph).* (Aviation, Vol. 40, No. 7, July, 1941, p. 122.)

66 29047 U.S.A. ... *Production of Bell P-39 (Airacobra).* (Aero Digest, Vol. 38, No. 5, May, 1941, pp. 72-75.)

67 29049 U.S.A. ... *Brewster Model 339 Fighter (Buffalo) (Photograph).* (Aero Digest, Vol. 38, No. 5, May, 1941, p. 84.)

68 29050 U.S.A. ... *New Brewster SB2A-1 Dive Bomber (Sketch).* (Aero Digest, Vol. 38, No. 5, May, 1941, p. 84.)

69 29055 U.S.A. ... *Me. 110 Fighter Examined by American Experts.* (J. E. Thompson, Aero Digest, Vol. 38, No. 5, May, 1941, pp. 155-167.)

70 29069 U.S.A. ... *25 Years of Army Aviation.* (H. H. Arnold, Aviation, Vol. 40, No. 8, Aug., 1941, pp. 54-55, 218-222.)

71 29081 U.S.A. ... *Curtiss SNC-1 Combat Trainer.* (Aviation, Vol. 40, No. 8, Aug., 1941, pp. 105, 232.)

72 29082 U.S.A. ... *Hawker Typhoon and Napier Sabre.* (P. H. Wilkinson, Aviation, Vol. 40, No. 8, Aug., 1941, p. 108.)

73 29083 U.S.A. ... *R.A.F. Bombing and Night Flying Trainer "Snargasher."* (Aviation, Vol. 40, No. 8, Aug., 1941, p. 111.)

74 29086 U.S.A. ... *Air Power and Coast Defence.* (T. R. Phillips, Army Ordnance, Vol. 22, No. 128, Sept.-Oct., 1941, pp. 217-220.)

75 29112 Switzerland ... *Towards the Total Aerial War.* (C. Rougeron, Flugwehr und Technik, Vol. III, No. 7, July, 1941, pp. 155-157.)

76 29113 Switzerland ... *Shipborne Reconnaissance Float Seaplane Arado AR. 196.* (Flugwehr und Technik, Vol. 3, No. 7, July, 1941, pp. 171-172.)

78 29143 France ... *The Defence of the Ship Against Aircraft Attack.* (A. Fournier, La Science et la Vie, Vol. 60, No. 289, Sept., 1941, pp. 124-137.)

79 29144 France ... *Modern Camouflage Principle.* (A. Daulnay, La Science et la Vie, Vol. 60, No. 289, Sept., 1941, pp. 138-146.)

80 29145 France ... *The Russo-German War (22nd June-1st Aug.).* (La Science et la Vie, Vol. 60, No. 289, Sept., 1941,, pp. 147-154.)

81 29147 France ... *Aerial Bombardment of Naval Construction Yards.* (C. Rougeron, Science et la Vie, Vol. 60, No. 289, Sept., 1941, pp. 163-174.)

82 29149 U.S.A. ... *Consolidated Catalina.* (Aircraft Engineering, Vol. 13, No. 152, Oct., 1941, pp. 280 and 283.)

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84 29178 France ... *How Can Gibraltar be Attacked?* (P. Bellerache, La Science et la Vie, Vol. 60, No. 288, Aug., 1941, pp. 65-72.)

85 29179 France ... *The State of the Soviet Air Force on 22/6/41.* (P. Camblanc, La Science et la Vie, Vol. 60, No. 288, Aug., 1941, pp. 73-79.)

86 29180 France ... *The Armouring of Aircraft.* (C. Rougeron, La Science et la Vie, Vol. 60, No. 288, Aug., 1941, pp. 94-105.)

87 29181 Germany ... *Modern Auxiliary Infantry Weapons.* (V. Reniger, La Science et la Vie, Vol. 60, No. 288, Aug., 1941, pp. 100-111.)

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88 28911 Great Britain *The Velocity of Diffusion in a Mixed Gas (Second Approximation).* (S. Chapman, Procs. of Roy. Soc., Vol. 179, No. 977, 10/10/41, pp. 159-169.)

89 28923 U.S.A. ... *Visual Experimentation with Centrifugal Pumps (Transparent Model).* (H. L. Cooper, J. Am. Soc. Nav. Engs., Vol. 53, No. 3, Aug., 1941, pp. 513-532.)

96 29174 Germany ... *Six-Component Measurements Over a Range of Angle of Yaw on Rectangular Wings with Dihedral and Sweep Back.* (E. Moller, L.F.F., Vol. 18, No. 7, 19/7/41, pp. 243-252.)

97 29177 Germany ... *General Airfoil Theory.* (H. G. Küssner, L.F.F., Vol. 17, No. 11-12, Dec., 1940.) (R.T.P. Translation No. T.M. 979.)

98 29185 Germany ... *The Effect of Aerodynamic Characteristic on the Sound Distribution and Radiating Capacity of an Airscrew.* (W. Frusthauser, L.F.F., Vol. 18, No. 8, 20/8/41, pp. 289-304.)

99 29186 Germany ... *An Integral Equation for the Rotating Blade Star and its Solution.* (W. Kucharski, Z.A.M.M., Vol. 21, No. 2, April, 1941, pp. 65-79.)

100 29187 Germany ... *The Geometrical Interpretation and the Transformation of the Fundamental Equation of the Two-Dimensonal Potential Flow of a Compressible Fluid.* (M. Pini, Z.A.M.M., Vol. 21, No. 2, April, 1941, pp. 80-85.)

101 29188 Germany ... *Flow Through a Plane Annular Slot of Varying Thickness.* (K. Voelz, Z.A.M.M., Vol. 21, No. 2, April, 1941, pp. 85-91.)

102 29192 Germany ... *On the Connection Between Some Formulæ for the Hydrodynamic Lift.* (F. Jung, Z.A.M.M., Vol. 21, No. 2, April, 1941, pp. 108-114.)

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106 28755 U.S.A. ... *Air Conditioning for Transport Planes.* (A. E. Smith, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 169-173.)

107 28756 U.S.A. ... *Choice and Application of Flexible Shafts in Aircraft.* (H. Chase, Aero Digest, Vol. 31, No. 1, July, 1941, pp. 174-182.)

108	28794	U.S.A. ...	*Lockheed Pump for Aircraft High Pressure Hydraulic Circuit.* (Airc. Prod., Vol. 111, No. 36, Oct., 1941, p. 361.)
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112	28828	U.S.A. ...	*Ocean Air Transport.* (J. T. Trippe, J. Roy. Aeron. Soc., Vol. 45, No. 369, Sept., 1941, p. 286.)
113	28854	Great Britain	*Routine Production Testing of Aircraft.* (Flight, Vol. 40, No. 1,711, 9/10/41, pp. 232-234.)
114	28855	Great Britain	*Aerodrome Levelling.* (Flight, Vol. 40, No. 1,711, 9/10/41, pp. c-d.)
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116	28867	Great Britain	*Electric Power in Aircraft, I.* (T. B. Holliday, Aeroplane, Vol. 61, No. 1,585, 10/10/41, pp. 404-405.)
117	28876	Germany ...	*The Aerodynamics of the Aircraft Model (Digest).* (F. W. Schultz, Luftwissen, Vol. 8, No. 8, Aug., 1941, p. 263.)
118	28880	Italy	*The Mechanics of Horizontal Flight (from the Italian).* (G. Everling, Luftwissen, Vol. 8, No. 8, Aug., 1941, pp. 256-259.)
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120	28888	Great Britain	*Contra Rotating Airscrew Torque (Discussion).* (Flight, Vol. 40, No. 1,712, 16/10/41, pp. 264-265.)
121	28947	U.S.A. ...	*German Air Systems in South America.* (American Aviation, Vol. 5, No. 7, 1st Sept., 1941, p. 40.)
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486 29130 U.S.A. ... *The Radiosonde.* (E. T. Clark and S. A. Karff, J. Frank. Inst., Vol. 232, No. 3, Sept., 1941, pp. 217-238.)

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488 29146 U.S.A. ... *Vibration Convertion for H.T. of Portable Battery Wireless Sets.* (Sci. Am., Vol. 165, No. 4, Oct., 1941, pp. 214-215.)

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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(Prepared by R.T.P.)

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Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

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NOTE.—As far as possible, the country of origin quoted in the items refers to the original source.

LIST OF ABBREVIATIONS OF TITLES AND JOURNALS.

A.	Abstracts from the Scientific and Technical Press.
Aeron. Eng.	Aeronautical Engineering (U.S.S.R.)
Aer. Res. Inst. Tokyo	Aeronautical Research Institute of Tokyo.
A.C.I.C.	Air Corps Information Circular.
Ann. d. Phys.	Annalen der Physik
Army Ord.	Army Ordnance.
Autom. Eng.	Automobile Engineer
Autom. Ind.	Automotive Industries.
Autom. Tech. Zeit. ...	Automobiltechnische Zeitschrift.
Bell Tele. Pubs. ...	Bell Telephone Publications.
Bur. Stan. J. Res. ...	Bureau of Standards (U.S.A.) Journal of Research.
Chem. Absts.	Chemical Abstracts.
Chem. and Ind. ...	Chemistry and Industry.
Comp. Rend.	Comptes Rendus de L'Académie des Sciences.
Eng. Absts.	Engineering Abstracts.
E.N.S.A.	Revue Technique de l'Association des Ingénieurs de l'Ecole Nationale Supérieure de L'Aéronautique.
Forschung	Forschung auf dem Gebiete des Ingenieurwesens.
Fuel	Fuel in Science and Practice.
H.F. Technik.	Hochfrequenztechnik und Elektroakustik.
Ind. and Eng. Chem. ...	Industrial and Engineering Chemistry.
Ing.-Arch.	Ingenieur-Archiv.
Inst. Autom. Eng. ...	Institute of Automobile Engineers (Research and Standardisation Committee).
J. Aeron. Sci.	Journal of the Aeronautical Sciences.
J. App. Mech.	Journal of Applied Mechanics.
J. Am. Soc. Nav. Engs.	Journal of American Society of Naval Engineers.
J. Roy. Aero. Soc. ...	Journal of Royal Aeronautical Society.
J. Frank. Inst.	Journal of Franklin Institute.

J. Inst. Civ. Engs. ...	Journal of Institute of Civil Engineers.
J. Inst. Elec. Engs. ...	Journal of Institute of Electrical Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Met. Soc.	Journal of Meteorological Society.
J. Sci. Inst.	Journal of Scientific Instruments.
J. Soc. Chem. Ind. (Abstracts B)	Journal of the Society of Chemical Industry (British Chemical Abstracts B)
J.S.A.E.	Journal of Society of Automotive Engineers.
L'Aéron.	L'Aéronautique.
L.F.F.	Luftfahrt-Forschung.
Luschau.	Luftfahrt-Schrifttum des Auslandes
Met. Mag.	Meteorological Magazine.
Met. Prog.	Metal Progress.
N.A.C.A.	National Advisory Committee for Aeronautics (U.S.A.).
Phil. Mag.	Philosophical Magazine.
Phil. Trans. Roy. Soc.	Philosophical Transactions of the Royal Society.
Phys. Berichte. ...	Physikalische Berichte.
Phys. Zeit.	Physikalische Zeitschrift.
Proc. Camb. Phil. Soc.	Proceedings of Cambridge Philosophical Society.
Proc. Inst. Rad. Engs.	Proceedings of Institute of Radio Engineers.
Proc. Roy. Soc. ...	Proceedings of Royal Society.
Pub. Sci. et Tech. ...	Publications Scientifiques et Techniques du Ministère de l'Air.
Q.J. Roy. Met. Soc. ...	Quarterly Journal of the Royal Meteorological Society.
R. and M.	Reports and Memoranda of the Aeronautical Research Committee.
Rev. de l'Arm. de l'Air	Revue de l'Armée de l'Air.
Riv. Aeron.	Rivista Aeronautica.
Sci. Absts. (A. or B.)	Science Abstracts (A or B.).
Sci. Am.	Scientific American.
Sci. Proc. Roy. Dublin Soc.	Scientific Proceedings of Royal Dublin Society.
Tech. Aéron.	La Technique Aéronautique.
Trans. A.S.M.E. ...	Transactions of the American Society of Mechanical Engineers.
Trans. C.A.H.I. ...	Transactions of the Central Aero-Hydrodynamical Institute, Moscow.
U.S. Nav. Inst. Proc.	U.S. Naval Institute Proceedings.
Veröffent (Siemens)	Veröffentlichungen aus dem Gebiete der Nachrichtentechnik (Siemens).
W.R.H.	Werft Reederei Hafen.
W.T.M.	Wehrtechnische Monatshefte.
Z.A.M.M.	Zeitschrift für Angewandte Mathematik und Mechanik.
Z.G.S.S.	Zeitschrift für das gesamte Schiess- und Sprengstoffwesen mit der Sonderabteilung Gasschutz.
Z. Instrum.	Zeitschrift für Instrumentenkunde.
Z. Mech.	Zentralblatt für Mechanik.
Z. Metallk.	Zeitschrift für Metallkunde.
Z.V.D.I.	Zeitschrift des Vereines Deutscher Ingenieure.

New Solution of the First Main Problem of External Ballistics. (K. Eggers, Wiss. Abh. Reichsamt f. Wetterdienst, Vol. 5, No. 11, 1939, pp. 11-16.) (96/1 Germany.)

The paper is a development of Popoff's investigations as laid down in "The Main Problem of External Ballistics," Leipzig, 1932. The motion of the projectile is related to a system of co-ordinate axes $\bar{x}$, $\bar{z}$, intersecting at an acute angle, and adapting itself step by step (by partial arcs), to the development of the trajectory. Calculation is based on a zone law for the air resistance $F(v)$, which is developed into a series $F(v)/v = f(v) = f(w) + \ldots$, with $w = \bar{x} + \bar{z}$. If this series is interrupted after the first term the variables in the equations of motion can be separated. It is then possible to find the time of flight t and the horizontal velocity $\bar{x}$, in terms of w. The error in each individual step arising out of this approximation, and the propagation of the error into the final values are exhaustively investigated.

The method can be improved either by selecting the limits of the stages of the calculation so as to cause the error arising from the neglect of the second term in $F(v)/v$ to assume partly positive and partly negative values within the stages (in this case the total error at the end of the stage is practically zero);

or by substituting a mean value (constant over the stage) for the variable factor in the neglected second term of the expansion. A check of the method by Cranz's standard trajectory gave good results.

To enable convenient calculation of an entire family of trajectories for setting up a range table, a number of basic integrals must first be calculated, of which the simplest has the form :—

$$A(\tilde{g}_o, w) = \int_{w_o}^{w} dw / \{ \tilde{g}_o - c_o F(w) \} \; ; \; \tilde{g}_o = \text{const.} \; ; \; c_o = \text{const.}$$

No information on the time taken by the new method is given. According to the abstracter, it is considerably more than the time required to calculate a range table by existing methods (Runge-Kutta, Cranz-Rothe). One disadvantage is that these integrals need evaluation, not only for each type of air resistance $F(w)$, but also for each projectile (c_o).

The variation of gravity, air density, and temperature with altitude, is to be allowed for by replacing these variables at each stage of the calculation by their corresponding, constant " ballistic " equivalents. Finally, a method for including the diurnal influences of air density, longitudinal and lateral winds, is indicated, entirely new formulæ being developed for the wind effect. The opinion of the author, that the methods hitherto current in ballistic practice for calculation of the relative wind effect are erroneous, is not shared by the abstracter.

(Abstract from Zent. B, Vol. 10, No. 4, 11/11/40, pp. 151-152.)

Ballistics of Anti-Aircraft Gunnery. (I. Lintes, C.R. Inst. Sci., Roum., Vol. 3, 1939, pp. 263-268, 549-558, 683-690.) (96/2 Roumania.)

1. The Calculation of Ballistic and Atmospheric Corrections for Anti-Aircraft Fire.

The starting point is the solution of the ballistic problem derived from the approximate principal ballistic equation (C. Cranz, " External Ballistics," Berlin, 1925, pp. 151 and 153). The author assumes an exponential law $[F(w) = Cw^n]$ for the air-drag function. On this assumption, he develops equations for variation of the horizontal distance dx/x, height dz/z, and time of flight dt/t, which are linked with variation of the muzzle velocity, angle of departure, and ballistic coefficient. These equations include as a special case, the familiar difference formulæ of Stübler (C. Cranz, supra, p. 282), and are applied to determine the effects of wind and rain on the trajectory.

2. Anti-Aircraft Ballistics (Nadiral Ballistics).

A method is developed, subject to certain limiting conditions, for the calculation in a self-contained form of the ascending limb of a trajectory. The assumptions are equivalent to making the ratio $\gamma = w/v$ (w = retardation due to air drag; v = projectile velocity) a function of the time of flight t, of the form $\gamma(t) = \gamma(o)/[1 + \gamma(o) \cdot t]$.

By means of this method, calculations are made for the envelope of the family of trajectories, the lines of equal inclination to the horizontal, equal times of flight, equal elevation and of equal fuse-setting. In the opinion of the abstracter, the equation for $\gamma(t)$ is only a rough approximation to the actual conditions.

3. Aerial Ballistics (Zenithal Ballistics).

For notation, see preceding abstract. On the assumption that from the vertex S onwards, the ratio $\gamma = w/v$ takes the form $\gamma(t) = \gamma_s/(1 + \gamma_s \cdot t)$, the (x, z)—co-ordinates of the descending limb of the trajectory of a projectile or an aerial bomb are calculated in a self-contained form as functions of the time t. In the opinion of the abstracter, the equation for $\gamma(t)$ is inapplicable to the descending part of the trajectory.

(Abstracts from Zent. B., Vol. 10, No. 4, 11/11/40.)

On Tactical Requirements in the Design of Fighter Aircraft. (J. P. Nikolaef, Aeronautical Engineering, U.S.S.R., Vol. 15, No. 3, March, 1941, pp. 56-58.) (96/3 U.S.S.R.)

A rejoinder to an article under the same title by M. P. Stroyev in "Aeronautical Engineering," U.S.S.R., No. 12, of 1940 (R.T.P. Abstract No. 28,109), specifically dealing with the contention of the original author that the twin-engined single-seater fighter type presents no advantages by comparison with the "Standard" single-engined fighter (*i.e.*, with a tractor airscrew).

As against this, the development of the latest fighter types as twin-engined models—*cf.* Grumman "Skyrocket," Lockheed "P.38," Westland "Whirlwind"—appears to prove that the twin-engine arrangement does have certain advantages, which are accordingly examined.

Treating manœuvrability as a function of the power loading (G/Ne in kg./h.p.), it is found that single engined types have power loadings between 2.6-2.7 kg./h.p., and twin-engined types between 2.2 and 2.3 kg./h.p.

Calculating the "coefficient of manœuvrability" $(G/N)\sqrt{(G/lS)}$—where G=all-up weight, N=engine h.p., l=wing span, S=wing area) the following values are obtained:—

Single-engined fighters:—	
Curtiss "Hawk"	20
"Spitfire"	19.5
"Me. 109"	18.5
Twin-engined fighters:—	
Grumman "Skyrocket"	17
Lockheed "P.38"	20

Manœuvrability and power loading being approximately the same in both groups, the conclusion is justified that the efficiency is also the same. Stability and controllability (with suitable design!) will be no worse for the twin-engined than the single-engined type. Top speeds are at least 5-6 per cent. better. The arrangement of two engines admits better provision for armament and fuel (longer range!), and avoids "blind spots" for the pilot.

The following conclusions are arrived at:—

1. The design of the twin-engined single-seater fighter, particularly with air-cooled engines, affords considerable tactical advantages in flight by comparison with the single-engine design.
2. In aerial combat the twin-engined fighter will be better by reason of higher speed, vertical manœuvrability, service ceiling, armament and visibility for the pilot.
3. Operations against bomber aircraft will be easier for the twin-engined fighter by reason of its greater fire power. This will also be useful for anti-tank operations.
4. The additional operational scope of the twin-engined fighter will be far greater.

The Oerlikon "Oblique Pin" Impact Fuse for 20 mm. Aircraft Cannon. (Flugwehr and Technik, Vol. 3, No. 6, June, 1941, pp. 161-162.) (96/4 Switzerland.)

Aircraft cannon ammunition must be safe during transport and whilst in the gun. This is usually achieved by providing a locking pin which is ejected by centrifugal action (spin) when the shell leaves the barrel. Cases having arisen when the ejected pin caused damage to the aircraft, the Oerlikon firm have developed an alternative safety device, still operated by centrifugal action, but retained in the shell and not ejected. The device consists of two inclined cylindrical members, pressed inward by a retaining spring and gripping the striking pin of the shell. The angle of inclination is so chosen that the inertia

forces due to longitudinal acceleration overbalance the centrifugal forces due to spin as long as the shell is still moving along the barrel. In free flight, however, the longitudinal acceleration stops and the cylindrical members now move outward under centrifugal force and free the striking pin. It is stated that the new type of fuse is perfectly safe during transport (dropping, shaking, blows, etc.), and has been designed specially to take into account present day difficulties in obtaining materials. Thus no copper is required in its manufacture.

Some Notes on Repair and Maintenance at an Advance German Air Base in Sicily. (Junkers Journal, Vol. 12, No. 5-6, May-June, 1941, pp. 70-72.) (96/5 Germany.)

Repair and maintenance units of the German Air Force are known by the initials F.B.K. and are provided with a number of lorries carrying the necessary tools and equipment so that a change of base can be carried out quickly. A mobile power plant supplies the necessary electric current. Photographs illustrate work being carried out on Ju. 88 bombers and include welding operations, engine overhaul (dust proof tent) and replacement of complete power plant.

Some Properties of the Hodograph and Their Application in the Construction of the Hodograph in the Problem of External Ballistics. (T. Lewis, Phil. Mag., Vol. 32, No. 214, Nov., 1941, pp. 427-435.) (96/6 Great Britain.)

The equations of motion of a projectile in a resisting medium can be integrated analytically only for special forms of the law of resistance and, except for the case in which the resistance is proportional to the velocity, the analysis is very complicated and great labour is involved before numerical results are obtained. The equations for an arbitrary law of resistance can be solved numerically with any degree of precision required. But all the calculations have to be repeated for every set of initial conditions and for each value of the ballistic coefficient. The labour of integration would be greatly reduced if the hodograph were known beforehand, or if a quick method of constructing the hodograph were known. Knowledge of the hodograph is equivalent to the knowledge of a first integral of the equations of motion.

The author shows that the tangents to all hodographs at the points corresponding to the velocity v pass through a fixed point on the y' axis provided c, the ballistic coefficient, remains constant. This property leads to a quick method of constructing the hodograph, which is described. It can be extended so as to allow for the variation of density and it does not require the construction of a different set of curves for each value of c; all that is needed is polar graph paper and tables of values of η, which can be calculated from the tables for $f(v)$.

Owing to the uncertainty in the value of the ballistic constant, it is of greater importance to be able to calculate accurately the difference in the elements of two trajectories due to a change in the initial conditions. If the difference in the initial conditions is a small quantity of order Δv, it follows that the error in the difference at any stage, due to the method of constructing the hodograph alone, is of the third order. So considered as a graphical method it appears to be highly satisfactory.

The Design of High Speed Military Aeroplanes. (C. L. Johnson, J. Aeron. Sci., Vol. 8, No. 12, Oct., 1941, pp. 467-474.) (96/7 U.S.A.)

The hardest problem which the designer of military aeroplanes must face is the proper evaluation of the following fundamental factors in their relative importance, one to the other:—

(*a*) Performance.
(*b*) Armament.
(*c*) Ease of production.

(*d*) Manœuvrability.
(*e*) Time required for development.
(*f*) Flight qualities.
(*g*) Cost.

All aircraft design is made up of compromises between these considerations and the success of the basic design depends on which of the above factors have been favoured without too great a loss in the other items. The element of time is of paramount importance under wartime conditions because the manufacturer, or, more properly, the nation, cannot afford to gamble too far on new and untried design features for fear that trouble experienced in their development may make the aeroplane obsolete and waste the production facilities at a time when the greatest output is required. It is better to have 1,000 four hundred m.p.h. aeroplanes in service than to have the finest four hundred and fifty m.p.h. design in the world on paper struggling with problems of design and production. Only after sound fundamental research and the highest type of engineering can the manufacturer afford to use some of the newer developments now on the horizon of progress.

A gross weight analysis of a typical twin-engine fighter is given below.

I.		II.	
Useful load, pilot, fuel, armour, guns	23.61%	Pilot, fuel, oil	14.5%
Wings	12.30	Stressed material	28.0
Tail unit	2.82	Miscellaneous material ...	12.5
Landing gear...	5.67	Purchased equipment (engine, prop., etc.)	45.0
Fuselage and fixed equipment	11.00		
Nacelles	8.30		
Power plant, propellers, fuel, and cooling systems ...	36.30		

The designer thus has direct control over only 40 per cent. of the gross weight.

As aeroplane speeds increase, the percentage of weight in the power plant increases also. Developments in the present war have shown the need for increased equipment rather than a reduction of what is now used. It can be seen that future military aeroplanes tend to become larger and more expensive as the performance is pushed up.

In spite of the fact that the pusher propeller has many problems, it seems fairly certain on the basis of present data that it should be used. Before they can be widely used, the problem of the pilot leaving the aeroplane with parachute must be considered. With a rotating propeller behind him, it is absolutely impossible to leave the aeroplane safely, so means for stopping it in a given position, dropping it or throwing the pilot clear, must be incorporated.

Visual Experimentation with Centrifugal Pumps (*American Society of Naval Engineers*). (H. L. Cooper, Engineer, Vol. 172, No. 4,476, 24/10/41, pp. 278-281.) (96/8 U.S.A.)

The tests were carried out on a 1 : 6 model of a 28 in. dredger pump. The model was of composite construction (transparent plastic and light alloy). Velocity and pressure distribution were obtained by means of pitot tubes and flow conditions were examined by means of silk threads.

Outstanding phenomena, brought to light as a result of this visual investigation, are the existence of large dead water areas within the impeller and the consequent existence of extremely high velocities over a small percentage of the cross-sectional area within the impeller. The magnitude of these velocities is often six times the average for the entire area. On account of these extreme velocities, considerable energy losses occur as a result of the transformation from

potential to kinetic energy, and vice versa. It is believed that these losses may be materially reduced by changes in design after further experimental effort.

The phenomena of dead water areas and maldistribution of velocities are also existent in conjunction with fluid flow through bends in pipes and conduits resulting in extensive energy losses. These influences must be detrimental to the transfer of fluid through the various piping systems of naval vessels, where space is at a premium and elbows, manifolds, and bends are in abundance. The decrease in power requirements and improvement in efficiency of these systems could well offset the cost of further experimental effort in this field.

Flow Properties of Lubricants Under High Pressure (with Discussion). (A. E. Norton and others, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 631-643.) (96/10 U.S.A.)

In this paper, results are given of a preliminary study of the rate-of-shear versus shear-stress relationship for several oils known to undergo apparent solidification when subjected to high pressure. Lard, rapeseed, sperm, and one mineral oil were tested under a temperature range of −5 C. to 20 C. while subjected to pressures up to 50,000 psi. Experimental curves of flow versus pressure difference were obtained for capillary flow, and these curves were transformed mathematically to the desired curves of rate of shear versus shear stress. A brief discussion of some of the problems inherent in capillary testing of plastic materials is included in this report.

The consistency of an oil near apparent solidification is dependent upon time of application of pressure as well as upon the amount of pressure and the temperature. The consistency is very likely dependent upon the amount of shear as well.

The Characteristics of the Aerofoil with Discontinuities Along the Span, with Special Reference to the Effects of Cut-out. (T. Okamoto, Aero. Res. Inst., Tokyo, No. 208, May, 1941, pp. 207-263.) (96/11 Japan.)

The present paper deals theoretically with the aerofoil with discontinuities along the span (such as rectangular cut-out, flap or aileron) and consists of three parts. In the first part, the approximate method of calculating the lift distribution of the aerofoil with discontinuities is obtained, and it is shown that the method described may conveniently be used in practice with satisfactory accuracy. In the second part, the characteristics of the aerofoil with longitudinal slots are studied, and the special cases of the divided aerofoil and the aerofoil with cut-out are solved. The calculated results agree satisfactorily with the measured results. In the third part, the characteristics of the aerofoil with rectangular cut-out are calculated, showing that the calculated results agree satisfactorily with the experimental results. (Twelve references.)

The Friction and Heat Transmission Coefficients of Rough Pipes. (W. F. Cope, Procs. Inst. Mech. Engs., Vol. 145, No. 3, June, 1941, pp. 99-105.) (96/12 Great Britain.)

In a previous paper (Cope, Procs. I.Mech.E., Vol. 137, 1937, p. 165) an account was given of the simultaneous measurement of the heat transmission and friction coefficients of a series of smooth pipes of various shapes of cross section. The results formed the first part of a comprehensive research into the problem of heat transmission. The present paper, which describes the results of tests on rough pipes, forms the second section. Three pipes were tested, their internal surfaces being artificially roughened by a special knurling process which produced a series of pyramids geometrically similar in form but varying in absolute size from pipe to pipe. The roughness ratios (radius of pipe/height of pyramid) were approximately 8/1, 15/1, and 45/1. The apparatus used was basically the same as that used in the previous tests; the working fluid was

water, and the Reynolds number ranged from 2,000 to 60,000. The results indicate that when fully turbulent conditions are established, the roughness has very little effect on the heat transmission coefficient, but that in the transition region between laminar and fully turbulent flow, the roughness may increase that coefficient to considerably more than its value for a smooth pipe; and that the heat transmission graphs for the three pipes are in better agreement if shearing force velocity is used instead of mean velocity, in forming the non-dimensional parameters used for plotting purposes. The broad conclusions from the practising engineer's standpoint are (1) for a given pressure drop across a heat transmission apparatus more heat will be transmitted if the pipes are smooth than if they are rough; (2) the velocity of the working fluid will, of course, be greater with smooth pipes; and (3) the smooth pipe is more efficient if the comparison is made on a basis of heat transmission for equal power.

On the Statistical Theory of Turbulence. (C. L. Pekeris, J. Aeron. Sci., Vol. 8, No. 12, Oct., 1941, pp. 475-476.) (97/13 U.S.A.)

A method is given of determining the distribution function of turbulent velocities. The distribution function $P(u)$ of a component turbulent velocity $u(t)$ is defined as the probability that u shall have the value between u and $u+du$. The part $P_e(u)$ of $P(u)$ which is an even function of u can be determined by first measuring the mean with respect to time of $\cos zu(t)$ for all value of z. If this function be denoted by $\psi(z)$ the $P_e(u)$ is given by

$$P_e(u) = (1/\pi)\int_0^\infty \cos uz\psi(z)\,dz.$$

Design and Production Procedure for Prototype Aircraft. (N. N. Polikarpov, Aeronautical Engineering, U.S.S.R., Vol. 15, No. 5-6, May-June, 1941, pp. 1-8.) (96/14 U.S.S.R.)

The author examines the methods and procedure for the design and development of experimental (properly speaking—prototype) aircraft. The need for these is apparent from the tremendous scale of modern aerial warfare and the consequent imperative necessity of utilising materials and technical resources to the very best advantage. The modern military aircraft is becoming an increasingly complicated machine—comparable almost to a warship—and this, together with the large-scale production required, imposes the most stringent conditions on the designer.

Two methods of development are available—the design and construction of experimental machines and prototypes for series production as an ancillary activity of large construction plants; and the establishment of special "experimental" or "prototype" plants. Both have their advantages—the latter appears more efficient under conditions of high-pressure wartime production.

A full scheme of design and development, up to the stage of the "prototype series" capable of actual, operational testing, consists of the following steps:—

1. Examination of the problem and determination of the fundamental characteristics of the new design. Specialization and concentration on individual characteristics (speed etc.) should be avoided; the military aircraft should be an "all round" machine as far as possible. Scope for modification and "modernization" is essential.
2. Setting up the preliminary design (sketch plan).
3. Construction of the mock-up.
4. Preparation of the constructional drawings. For mass production this requires to be very carefully done.
5. Construction of the prototype series, followed by strength tests under both static and dynamic loads, vibration tests, etc.

6. Flight tests, preliminary and operational.
7. The type is passed into mass production.

Some design points to be watched:—

Durability of materials.
Rapid readiness for service.
Critical analysis of earlier designs which have failed in practice.
Control, take-off speed as well as landing speed; length of run in both cases.
Production methods and economy of materials.

Weight Reduction in Aircraft Design. (E. E. Roberts, Aero Digest, Vol. 39, No. 2, August, 1941, pp. 146-150, 232-233.) (96/15 U.S.A.)

As recently as ten years ago, the existence of a separate weight department as such was relatively unknown in aircraft plants. Necessary weight and balance calculation were made by personnel who could find the time to do them. Only within the last five years has the weight engineer elevated his function from that of estimating, calculating and recording, to one of actual control. The methods by means of which this has been achieved are described by the author with special reference to the Lockheed firm. Success can only be achieved if there exists the closest co-operation between the aerodynamic design and production departments. It is interesting to note that of the total (empty) weight of an aircraft, only about 50 per cent., covering the main structural parts such as wings, fuselage, etc., is controlled by the firm.

The remainder represents purchased equipment (power plant, etc.) or parts supplied by the Government (armament, etc.).

Excluding such items as ducts, fairings, pipe line and electric wiring, seats, flooring, etc., less than 30 per cent. of the empty weight remains in the form of stressed material under full control of the aircraft firm. It is evident that further progress is only possible if the firm or Government departments supplying the non-structural equipment are rendered as "weight conscious" as those responsible for the complete aircraft.

Photo-Loft-Template Process Film Developed. (Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 196-198.) (96/16 U.S.A.)

With the use of Matte Transfer Film, developed by Kodak, engineering drawings can be printed either by contact or by projection on photo-sensitive metal sheets and the processed plates bearing the photographic image are then sent directly to the Template Department to be cut out and used as a pattern. The templates are made by cutting around the photographic outline by a saw or mechanical shears. Other machining operations to which the photo-sensitised metal sheets are subjected are filing, drilling and punching. By this means the costly and time-consuming step of making the layouts on metal by hand from the blueprints or the necessity of duplicate inspection is avoided. Also, by this method, copies of a drawing can be produced for checking purposes, for blueprints, (by using photographic tracing cloth), or for use in re-designing a part.

In the contact method of making prints on photo-sensitised metal, the engineering drawings are made on metal plates which have been given a coating of a material which will fluoresce in the presence of X-rays. This coating is likewise of such a nature that it can be drawn upon satisfactorily. If positive prints on the metal are desired, a photo-sensitive glass plate is placed in contact with a treated surface of the plate bearing the mechanical drawing and the exposure is made by X-ray through the back of the metal plate. The processed glass negative is then printed on to a sheet of photo-sensitised metal in the usual way. If a mirror image negative on metal is used for the templates, the photo-sensitised metal sheet is placed in contact with the above treated metal drawing sheet and exposed through the back of the metal by X-ray.

The negative mirror images obtained may be made into " right " images by simply turning over the finished template.

Lockheed Aircraft Corp., a pioneer user of Eastman Matte Transfer Film, has made satisfactory use of enlargements of mechanical drawings on photo-sensitised metal plates. In this process the mechanical drawings are made directly upon lacquered metal sheets. The drawings are then photographed on glass plates in a special camera. The glass negatives are then enlarged on to the photo-sensitised metal sheets. By this method photo-templates as large as 4 ft. by 12 ft. have been made.

It has been found that the most simple and effective method of producing sheets of photo-sensitised metal consists of laminating Matte Transfer Film to lacquered metal sheets. The film consists of a sensitive emulsion coated on a thin film support, the latter backed by a paper base. When used, the sensitised strip is transferred (or stripped) from the supporting paper base to the lacquered metal plate. This film has a matte surface, so that it will take a pencil line in case changes or additional developments on the processed photographic image are desired.

At present, width of Matte Transfer Film is limited to a maximum of 34.5 in. If wider plates are desired, several strips of film are used to give the desired width and the plate is passed through the machine the required number of times for proper lamination of the film.

Performance of Aircraft Wheels and Brakes. (H. Burkhardt, Luftwissen, Vol. 8, No. 9, September, 1941, pp. 289-291.) (96/19 Germany.)

A typical German aircraft wheel is described and illustrated. The body of the wheel is made of Mg. alloy with cast iron inserts for the two brake drums. Two oil-operated band brakes are fitted (one on either side). The wheel without tyre weighs about .012 kg. per kg. of static load and has a factor of safety of 8. In spite of the low weight, the quantity of material is ample to absorb and subsequently radiate the heat generated during the braking. This energy is very considerable and amounts to about 500 K cal per wheel for the case of an aircraft weighing 9,000 kg. landing at 160 km./hour and pulled up in 300 m. It is interesting to note that the brake lining contains no asbestos but consists of a highly polished steel strip mounted on buna rubber. The friction generated between this strip and the cast iron brake drum is satisfactory, provided both surfaces are highly polished and all grease or oil is excluded. For this reason all the ball bearings are fitted with buna sealing washers and require no subsequent lubrication.

The great art in wheel design is to combine lightness and small bulk with adequate shock-absorbing capacity (size of tyre). With the advent of retractable undercarriages, the dimension of the wheel will to some extent determine the depth of the wing required to house it and this has a direct effect on aero-dynamics characteristics.

The possibility of rapid replacement of the wheel as a whole in case of damage is also of importance. According to the author, the German design of wheel satisfies all requirements, besides needing only home-produced materials for its manufacture.

Range at Constant Speed. (N. B. Moore, J. Aeron. Sci., Vol. 8, No. 12, Oct., 1941, pp. 456-466.) (96/22 U.S.A.)

The difference, at constant speed, between the thrust horse-power required at the average weight, as commonly used in range estimates, and the exact " mean effective thrust horse-power " required over the weight interval is investigated. Use of this m.e.t.hp. in estimates of range at constant speed for high-altitude, heavily loaded aeroplanes is facilitated by curves giving it as a function of t.hp.

required at the initial weight, of the ratio of final to initial weights, and of the basic performance parameter Δ_{z_1} at the initial weight of the aeroplane.

Cable Weights of Electrical Installations in Aircraft. (E. Ruhlemann, Flughafen, Vol. 9, No. 4, April, 1941, pp. 3-5.) (96/23 Germany.)

Details of the electric cable system on a Dornier aircraft (unspecified) are given. The cable range from multi-strand (5 mm.^{2} cross section of each wire) to single wires of 25 mm.^{2} cross section. On a basis of actual length of wire used (i.e. in the case of multi-strand, length of cable × number of strands) the smaller cross sections up to 1.5 mm.^{2} account for over 90 per cent. of the total length installed. Of this 90 per cent., 60 per cent. are accounted for by wires up to .75 mm.^{2} cross section. On a weight basis, however, sections up to 1.5 mm.^{2} account for only 60 per cent. of the total, the remaining 40 per cent. being made up by sections of 2.5 mm.^{2} and above. This weight basis of course refers to the complete cable, copper core plus insulation. It is interesting to note that the total weight of insulation of all the cable is roughly equal to the total weight of metal and from the point of view of weight reduction, both materials are thus equally important. The general substitution of Al. for Copper has not found favour in aircraft installations due to corrosion difficulties, especially for the smaller sections. Since, however, the larger sections (2.5 mm.^{2} and upwards) account for 27 per cent. of the total metal weight, the utilisation of Al. for the heavier sections is well worth considering. It is stated that the substitution of synthetic materials for the normal rubber insulation would lead to a reduction in weight of the total installation by about 10 per cent.

Flexible Couplings for Internal Combustion Engines (with Discussion). (J. Ormondroyd, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 577-582.) (96/24 U.S.A.)

Four typical dynamical cases of torsionally flexible "linear" couplings are examined: (1) Instantaneous applications of the maximum engine torque; (2) instantaneous stoppage of the engine or the driven member; (3) dangerous torsional resonance; and (4) tooth chatter in geared drives.

In this paper only the effects of the elastic properties of the couplings have been considered. The ability of the flexible elements to withstand the twisting torques encountered in operation has been completely omitted. A great variety of couplings could be used to get the same flexibility. Each one considered would have to be analysed to ascertain its adequacy to meet the operating conditions at resonance. If it is strong enough to take the torques at resonance safely, it is more than safe at all other operating speeds. The most general remark that can be made in this connection is that safety in a flexible coupling is to be attained by using the largest possible volume of elastic material which gives the desired spring constant in the space available for the coupling. Also, the most efficient use of elastic materials in couplings is obtained by stressing the materials in pure tension, pure compression, or pure shear. This is usually only practical in couplings in which rubber is the elastic medium. Where metals form the elastic elements, reasonable deflections are obtained only by using the material in twist or bending. Under these modes of stressing, a fair percentage of the metal is not carrying large stresses, and either very high fatigue limits must be used or volumes of metal hard to pack into reasonable space limitations must be considered.

It is a popular misconception that flexible couplings which have torque-deflection curves that are not straight lines are cure-alls for torsional-vibration troubles. It is often imagined that torsional resonance cannot occur if such a coupling is introduced into the rotating systems. This belief may be based on the statements made by recognized authorities that no infinite amplitudes of motion are possible in a system which contains a non-linear coupling, even

if frictional damping were completely absent. While this is true, and it is also a fact that very complicated relationships exist between torque, frequency, and amplitude of motion, it should be understood that conditions resembling resonance with linear couplings also exist with non-linear couplings. Amplitudes of motion large enough to cause trouble can exist at certain frequencies even if non-linear couplings are used. The reader is referred to a paper entitled "Steady Oscillations of Systems With Non-Linear and Unsymmetrical Elasticity," by Manfred Rauscher, Trans. A.S.M.E., vol. 60, 1938, p. A-169. This paper indicates methods by which such couplings can be analysed and also refers to numerous other papers on this subject that could be perused to get a complete picture of the situation existing when non-linear couplings are used.

Rotating Boiler Turbine. (Nott, Eng. and Boiler House Rev., Oct., 1941, pp. 114, 116, 118 and 120.) (96/25 Great Britain.)

The author discusses the principle of operation, construction and tests of a novel light-weight steam power plant of the rotating "U" tube type, which is entirely self-contained, combining within a single housing the burners, boiler, turbine and condenser. It is claimed that the machine works satisfactorily with no reciprocating mechanism whatsoever. Pressurising of water takes place wholly under the action of centrifugal force. Results obtained with two models were successful enough to warrant the building of a larger unit of 100 kw. capacity. Thermal efficiency and specific weights of the rotating surfaces are also discussed.

(Abstract supplied by Research Dept., Met. Vick.)

Icing of Carburettor Air Induction Systems of Aeroplanes and Engines. (V. J. Skoglund, J. Aeron. Sci., Vol. 8, No. 12, Oct., 1941, pp. 437-464.) (96/26 U.S.A.)

In conjunction with the development of a new commercial air-line power plant installation, laboratory tests were made of the icing of all critical parts of the carburettor air induction system, from the air scoop entrance to the supercharger impeller. Flight tests were made to establish a basis for the laboratory tests. The laboratory programme and apparatus were examined by all concerned and the results obtained were compared with actual operating experience to insure that they had a direct practical application. Laboratory tests included about 75 runs of full scale icing of the scoop in an 18 × 36 in. refrigerated wind tunnel and about 275 full scale runs of carburettor and engine induction system icing with a selected fuel in a complete running engine rear section. A laboratory was constructed for the latter tests, which included refrigeration, heating, and humidification equipment for producing cold and pre-heated carburettor air over a wide range of conditions.

The results of this investigation were: (1) A recommendation for radical changes in the original design of an air scoop which should make it possible to operate the scoop, without danger, under the most severe impact icing conditions; (2) the effect of a wide range of a large number of variables on the formation of ice on all parts of the induction system; (3) the extent of the induction system icing hazards, and effectiveness of pre-heat in preventing and removing ice formed with a conventional type and a new type of fuel discharge nozzles; (4) the relative effectiveness of pre-heat and alcohol in removing induction system ice.

An extensive bibliography completes the article.

Engine Stresses Due to Rapid Rise of Combustion Pressure or Knock. (J. Geiger, A.T.Z., Vol. 44, No. 13, 10/7/41, pp. 327-335.) (96/27 Germany.)

The piston, connecting rod, crank throw combination in an engine forms an elastic system capable of undergoing longitudinal vibrations. The author reduces

this system to an equivalent 3 mass system which is subjected to the application of gas pressure varying according to some simple law. The response of the system, expressed in terms of the longitudinal force in the connecting rod, depends not only on the elasticity of the system and the gas pressure but also on the relation between natural frequency of the system and the periodicity of the applied force. Thus the rate of pressure rise, frequently put forward as the sole criterion, is not sufficient as a stress criterion of the engine transmission system. The force in the connecting rod may exceed the maximum explosion pressure by over 50 per cent. with quite moderate rate of pressure rise, provided the frequency of the gas cycle is of the order of .4 of the natural frequency of the system. The gas frequencies accompanying a knocking explosion are generally very high (8-10 times the natural frequency of the piston-rod-crank system) and the pressure accompanying knock are thus transmitted without amplification.

The author substantiates his conclusion by reference to piezo-electric records of the cylinder acceleration under various conditions of engine operation. For further confirmation, a previous paper by Le Mesurier & Stansfield is cited.

Time and Distance Computor. (Aero Digest, Vol. 39, No. 2, August, 1941, p. 198.) (96/30 U.S.A.)

The instrument enables a pilot to formulate accurately and quickly a flight plan based on actual visual indications directly from the flight chart.

The instrument is set to the ground speed of the aircraft and is then placed on the standard aeronautical chart along the route to be flown. It will then indicate the time the aircraft will pass over landmarks or radio check points along the route to be flown.

In flight, when time is established between two points shown on the chart the actual ground speed made good will be indicated and a corrected estimate for time required between other points ahead on the chart will be shown by the instrument.

Two models are manufactured which provide computations for all present type aircraft with speeds up to 400 m.p.h. and are operated in connection with Coast Geodetic Survey Charts (U.S.A.). The instrument is 13.5 in. long and 1.25 in. wide, with fixed distance scales conforming with the scale of the aeronautical charts, and movable and expanding time scale to provide time distance ratio.

The near edge of the computor is the miles scale, reading 8 miles per inch, like the chart. In the centre of the computor is an elastic band 5/16 in. wide, attached at left end of computor and imprinted with divisions representing minutes. The right end of the elastic terminates in a cylindrical knob which permits locking at any point for any degree of extension desired. In use the computor is laid on map, the elastic scale is extended until the number of minutes coincides with the number of miles indicated between desired points on map. If these points are the leg of flight just completed, the distance to next point, actual ground speed made good, minutes to next check point or destination, etc., are instantly readable from scale without further setting or intermediate figuring.

Metal Rectifiers (with Discussion). (A. L. Williams and L. E. Thompson, J. Inst. Elect. Eng., Vol. 88, No. 10, Pt. 1, Oct., 1941, pp. 353-383.) (96/31 Great Britain.)

The paper deals in detail only with the two types of metal rectifier which have found general application in industry, namely the copper-oxide and selenium rectifiers.

The history of these is given briefly, with particular reference to the main developments which have brought them to their present state of efficiency. This section leads up to modern methods of manufacture.

The fundamental direct-current electrical characteristics, upon which the performance depends, and the manner in which they are influenced by various factors, are described.

The simple basic theory which governs all types of rectifier is discussed with reference to metal rectifiers in relation to their chemical and physical forms.

Finally, the method by which the correct working conditions are deduced from the characteristics is described.

Electrical Moisture Detector. (Mech. World, 10/10/41, p. 250.) (96/32 Great Britain.)

The determination of moisture in wood, plaster, masonry, acoustical and other materials is often a tedious operation involving weighing, drying and calculation. It is claimed for the Delmhorst Instrument, which is briefly described, that the range covered is from 8 to 24 per cent. of moisture in woods, being accurate to within 1 per cent. No skill is necessary in its operation, the electrode needles being plunged into the material, a dial turned and a direct reading in percentage is obtained. Electric power is supplied to the instrument by a self-contained battery.

(Abstract supplied by Research Dept., Met. Vick.)

Self Re-Winding Cable Reel. (Colliery Guardian, 3/10/41, pp. 288-289.) (96/33 Great Britain.)

In certain mobile electrically-driven equipment there are often objections, due to damage, deterioration and entanglement, to using long lengths of trailing cable. A self re-winding reel is described which can take cable up to 1.5 in. in diameter. Essentially, it consists of a metal rotating reel (with enclosed slip-rings) carrying the cable, which, on unwinding, operates a spring mechanism, similar in principle to the spring roller blind. It is claimed that the cable is always maintained at a suitable tension, but when the latter decreases, the cable is automatically re-wound by the action of the spring.

(Abstract supplied by Research Dept., Met. Vick.)

A Simple Method of Successive Approximations for Solving Equations of Elasticity. (R. V. Halasz, Bautechnik, Vol. 18, 1940, pp. 233-235.) (96/34 Germany.)

The author gives a series approximation for the solution of a linear equation of the type

$$\sum_h a_{kh}x_h - a_{ko} = 0$$

allowing the unknowns x_k contained in the principal diagonal to be calculated as functions of the remaining terms. Iteration commences with the approximation $x_k^{(1)} = a_{ko}$ and is conducted in separate steps, the improved results $x_1^{(\nu)} \ldots x_m^{(\nu)}$ of any iteration step ν being already used for the solution of $x_{m+1}^{(\nu)}$ of the same step.

As an aid to calculation a modification of the solution to enable use of the slide-rule is given.

(Abstract from Zentral B., Vol. 10, No. 3, 29/12/40, p. 103.)

Solution of Equations of Elasticity. (H. Borges, Beton u. Eisen, Vol. 39, 1940, pp. 120-124.) (96/35 Germany.)

The author deals with the solution of equations of condition for girder lattices and similar systems, having simple and double symmetry of the principal system. This leads to symmetry of the matrix about two or four main axes, and thus to subdivision of the calculation. By the addition and subtraction of equations of symmetrical order, two or four mutually independent partial groups are obtained equivalent statically to the introduction of redundant group loads. The

conjugated coefficients appertaining to the principal matrix are calculated by recursion from the solutions of the partial groups.

(Abstract from Zent. B., Vol. 10, No. 3, 29/10/41, pp. 104/105.)

Combustion Explosions in Pressure Vessels Protected with Rupture Disks. (M. D. Creech, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 583-588.) (96/37 U.S.A.)

The object of this investigation was the determination of the effectiveness of a rupture disk for relieving the rapid pressure rise in a pressure vessel during a combustion explosion of its contents. The experimental data presented here are merely a first step toward the solution of this problem. This matter is quite complicated and much must yet be learned about combustion explosions in general before the problem can be called solved. Many of the variables which might affect the results were either disregarded or only crudely or partially controlled. However, the results thus far obtained do indicate that by using a higher factor of safety in designing the vessel together with a rupture disk of suitable size, every vessel containing an explosive combustible mixture can be protected. For many of the less violently explosive mixtures, a rupture disk alone will give absolute protection from a destructive explosion.

The Permissible Stressing of Gears and its Calculation in Machine Tool Construction. (H. Hofer, Friedrichshafen Gear Wheel Company, Werkstattstechnik, Vol. 25, No. 5, 1/3/31, pp. 128-131.) (96/38 Germany.)

The various types of possible gear loading are reviewed and, according to the author, the most important stress is that resulting from the normal contact pressure between the flanks (crushing of material). The loading due to bending of the blade root or slip during contact can generally be neglected in comparison.

According to the Hertz theory of cylindrical contact, the permissible contact pressure of two cylinders at rest varies as the square of the material strength (mainly surface hardness) and the mean radius of curvature at contact. This shows the great importance of case hardened gears. In the stationary case, the limiting stress is the same for either cylinder, irrespective of diameter. If, however, the cylinders are in relative motion, the contact zones of high pressure have a higher frequency on the cylinder of smaller diameter and for this reason the author suggests that in the case of gear wheels, the actual radius of curvature of each flank should be considered. In the case of involute teeth, this radius of curvature on the pitch circle $= z\,(m/2)\sin\epsilon$ where

z = number of teeth.
m = modulus.
ϵ = obliquity of action.
(mz = diameter of pitch circle).
If P = maximum permissible circumferential force (kg.) (along pitch circle).
b = width of tooth (mm.),

the normal force on flank surface $= P/(b\cos\epsilon)$ per unit width of tooth.

Inserting this in the Hertz formula, we have

$$\frac{P}{b\cos\epsilon} = KR^2 \,.\, z\left(\frac{m}{2}\right)\sin\epsilon$$

where K = empirical factor.
R = Rockwell hardness of material.

This can be rewritten in the form

$S_a n R^2 z m \sin 2\epsilon$ = constant, which in the case of hardened ground gears with normal lubrication
$= 10^9$ for continuous operation and indefinite life
$= 10^8$ for very short life ($\simeq$ 50 hours) (n = r.p.m.)

In the above

$S_a = mzb/20N$ (N = h.p. transmitted)
$= 1$ to prevent excessive heating up of the gear.

At very low and very high speeds, $S_a \approx 2$ since under these conditions lubrication is imperfect. Inertia stresses due to inaccuracy of manufacture (non-uniform angular velocities) also put an upper limit to the permissible r.p.m.

Resistance Welding of Light Alloys. (*Original in Japanese.*) (R.W. Research Committee, Aero. Res. Inst., Tokyo, No. 210, May, 1941, pp. 301-482.) (96/39 Japan.)

The following are the factors controlling resistance welding:—

(1) Magnitude of welding current,
(2) Time of current flow,
(3) Mechanical pressure between electrodes,
(4) Material of electrodes,
(5) Shape of electrode tips,
(6) Material of the metal sheets to be welded,
(7) Thickness of the sheets,
(8) Surface conditions of the sheets.

An investigation of the resistance welding of light alloys is being carried on since 1936 at the Aeronautical Research Institute, Japan, with the collaboration of its five departments (Aircraft, Electrical Engineering, Materials, Metallurgy and Central Work Shop).

This report gives a general account of the resistance welding of light metals and the results of the investigations on spot welding up to the present.

A good many of the authorities on the subject have reported that in producing satisfactory welds, three of the variables—welding current, time and pressure—must be accurately controlled. According to the experiments in the Aeronautical Research Institute, however, the shape of electrodes is considered to be one of the most critical variables and the proper values of current, time and pressure cannot be recommended without the specification of the shape of electrodes.

At present the static shear strength of welds is already satisfactory. Under shock, welds of 1.5 to 2.0 mm. thickness have shown equal or better results than with 5 mm. rivets.

Under fatigue, however, the weld is inferior to the riveted joint. Subsequent mechanical treatment, however, can improve the strength characteristics of the weld and this is being investigated further.

New Gear-Tooth Flame Hardening Machine. (Iron Age, 28/8/41, p. 57.) (Met. Vick.) (96/40 Great Britain.)

The article describes a new machine for flame hardening the surfaces of sprockets, bevel, spur and internal gears up to 33 in. pitch diameter. It is stated that both sides of the tooth are hardened simultaneously without distortion, and that each tooth on the wheel is hardened to exactly the same depth. A non-rusting coolant is used. The machine is fully automatic after starting, even to the extent of indexing, rolling, pre-heating and hardening, also stopping the motor and shutting off the gas supply when all the teeth have been hardened.

(Abstract supplied by Research Dept., Met. Vick.)

Aircraft Spot Welding Problems (Digest). (M. M. Rockwell, J.S.A.E., Vol. 49, No. 4, Oct., 1941, p. 441.) (96/41 U.S.A.)

Aluminium alloys have low electrical resistance and high heat conductivity; hence very welding heavy currents and pressures must be used. Even then, most of the generation of heat occurs at the surface of contact between the sheets being welded.

These conditions have imposed difficulties which have somewhat retarded the application of spot welding in the aircraft industry. However, of recent years, development has come very rapidly.

The increase in requirements for spot welding equipment in turn brought to the fore a very serious problem—the magnitude of the power supply necessary for such equipment.

At this point a saving factor appeared in the form of the " stored-energy " type spot welder first introduced into the U.S.A. two years ago by a French firm. The " stored-energy " spot welder introduces a new principle—that of charging the transformer up slowly with magnetic energy, then discharging it quickly to make the weld.

Consistent maintenance of the proper pressure is essential to successful spot welding because pressure controls the surface contact resistance. In many machines, pneumatic force is used to produce electrode pressure and, if the air lines to the welder are too small, the air pressure will drop when the machines are operated rapidly, and mysterious troubles will ensue. It was found necessary to install a large air receiver near the welder to overcome this trouble. Hydraulic pressure systems should be a helpful improvement.

Probably the greatest single cause of spot welding trouble is improper surface preparation. Oil, grease, or paint left on the surface to be welded produce cracked, burned, weak, or even " blown " spots. Careful cleaning is essential and, in most cases, it is also necessary to remove part of the oxide film which always covers the surface of aluminium alloys.

Static Fatigue Life of Rubber. (S. M. Cadwell and others, S.A.E.J., Vol. 49, No. 4, Oct., 1941, pp. 442-447.) (96/42 U.S.A.)

Static fatigue of rubber is defined by the authors as a progressive breakdown under the influence of a static load, whereas dynamic fatigue is defined as the progressive loss of strength due to successive cycles of stress. The static fatigue life is the time required for rupture under a static load.

Test data presented on the tension static fatigue of rubber indicate that the static fatigue lives of the samples are functions of the stresses acting on them; that the static fatigue lives fall off rapidly with increasing stresses; and that the dependents of static fatigue life on the stress is a function of the stock, among other things.

Curves of reduction of tensile due to static fatigue show that the tensiles of samples under load actually decrease and that the decrease is greater, the greater the time under load.

Referring to the effect of degree of cure, the data indicate that resistance to static fatigue decreases as degree of cure is increased beyond a certain optimum value which varies with the stock.

Other data show that large flow during cure in a particular region reduced the static fatigue resistance of that region in comparison with the remainder of the body of the stock; and that lateral pressure is highly beneficial in increasing the static fatigue lives of bonded rubber parts used in shear.

Chafing (Fretting) Fatigue Strength of Some Metals and Alloys. (G. Sachs and P. Stefan, Trans. of Am. Soc. Met., Vol. 29, No. 2, June, 1941, pp. 373-401.) (96/44 U.S.A.)

Endurance tests on cylindrical bars offer a simple method for determining the effect of stress raisers on the fatigue strength. The resulting chafing fatigue strength appears closely related to the notch fatigue strength obtained on specimens with very severe notches. The effects of cold work and heat treatments on the regular and on the chafing fatigue strength respectively are very different. Generally, annealed wrought metals have a higher chafing fatigue strength but a lower regular fatigue strength than the harder cold-worked and heat-treated conditions. Cast steels

and aluminium alloys may have a higher chafing fatigue strength than wrought metals of the same type.

The trend curve for the chafing fatigue strength of the heat-treated cast al. alloys is located about 30 per cent. higher than that of the heat-treated wrought alloys. However, the actual differences are smaller, because the cast alloys have generally lower regular fatigue strength than the wrought alloys. The sand cast aluminium alloy, in particular, shows a lower chafing fatigue strength and even a lower regular fatigue strength than the chafing fatigue strength of the forged alloy.

It would appear, therefore, that suitably selected cast alloys may offer some advantage for applications where moving machinery parts are exposed to severe surface attacks by notches, corrosion and chafing.

Correlation of High Temperature Creep and Rupture Tests Results. (R. H. Thilemann, Trans. Am. Soc. Met., Vol. 29, No. 2, June, 1941, pp. 355-372.) (96/43 U.S.A.)

The tests were carried out on 4 in. specimen over periods up to 10,000 hrs. of exterpolated to 100,000 hrs. The results are given in table:—

Material.	Temp. of Test °F.	(SR) 100,000 Hour Rupture Stress (lb. sq. in.).	(SC)* 100,000 Hour 1% Creep Stress (lb. sq. in.).	Ratio (SR/SC)
Ni-Cr-Mo ...	900	20,000	13,500	1.48
Cr-Mo-V ...	1,000	22,000	22,000	1.00
C-½ per cent. Mo	1,000	9,000	7,300	1.23
7 per cent. Cr-Mo-Si	1,200	3,750	1,700	2.20

*Indicates total creep and should not be confused with 1 per cent. creep rate per 100,000 hour commonly used.

It appears that both the creep and rupture properties of a material must be known before the behaviour over long periods of time at elevated temperatures can be predicted with any degree of certainty. A combined plot of creep and rupture test results, as presented, is found to be useful in correlating the creep and rupture properties. This method of plotting affords a convincing means of arriving at safe working stresses for design purposes.

With some materials there is good reason to believe that the amount of elongation accompanying long time fractures will be very small indeed. Usually, these materials possess high creep strengths and fail by a process of intergranular cracking. As indicated by the results, for materials of this type, long-time factors of safety against failure may be almost lacking if design stresses are based on the value that will produce 1 per cent. of creep in 100,000 hours. On the same basis, materials that do not fail by intergranular cracking in tests of long duration usually show much larger factors of safety against failure.

The Vibration Damping Capacity of Mn-Cu. Alloys. (R. S. Dean and others, Trans. Am. Soc. Metals, Vol. 29, No. 2, June, 1941, pp. 402-414.) (96/45 U.S.A.)

Preliminary measurements showed that certain manganese-copper alloys which possess a remarkable deadness or lack of metallic ring also have unusually high vibration damping capacity at low stresses.

An instrument for the determination of this property is described and the results obtained with manganese-copper alloys are discussed.

The results indicate that the high values obtained by certain heat treatments are due to the formation of ordered anti-phase nuclei in the mass of the alloy.

The vibration damping capacity appears to reach a maximum with some critical distribution of these anti-phase nuclei and decrease as a state of equilibrium order is approached. The effect of cold work is to decrease the vibration damping capacity of the alloys as would be expected from its disordering effect. The unusually high vibration damping capacity of the quenched alloys drops with

time, and it is suggested that it is due to their failure to come to an equilibrium volume when quenched. There would thus seem to be simillarity in structure with regard to its effect on vibration damping capacity between an alloy in a super-cooled state and an alloy in a partly ordered state. In both instances, some of the atoms of the metal are not in the equilibrium positions required by the temperature. High vibration damping capacity appears to be an attribute of such metastable systems.

Fatigue and Damping Studies of Aircraft Sheet Materials (Dural Alloy 24ST, Alclad 24ST and Several 18-8 Type Stainless Steels). (R. M. Brick and A. Phillips, Trans. of Am. Soc. Metals, Vol. 29, No. 2, June, 1941, pp. 435-469.) (96/46 U.S.A.)

The strong wrought aluminium alloys, 24ST and Alclad 24ST, and nine 18-8 type commercial grades of stainless steels of low and moderate carbon contents, and in the annealed, cold-rolled, stabilized and aged conditions were fatigue tested under constant deflection conditions. The results are given in Tables 1 and 2:—

TABLE I.

Material.	Fatigue Strength 5×10 Pounds sq. in.	Probable 5×10^8 Cycle Endurance Limit Pounds sq. in.	Tensile Pounds sq. in.
24ST-L[1]	20,500[3]	18,000[4]	66,000
24ST-T[2]	18,500[4]	16,500[4]	65,000
Alclad-L	13,000[3]	11,000[4]	64,000
Alclad-T	11,500[3]	10,000[4]	63,000

[1] L-rolling direction parallel to specimen axis.
[2] T-rolling direction transverse to specimen axis.
[3] Error from stress measurement and extrapolation: $= \pm 1{,}000$ pounds per square inch.
[4] Error; $\pm 2{,}000$ pounds per square inch.

TABLE II.

RESULTS OF FATIGUE TESTS OF STAINLESS STEELS.

Alloy No.	Type and Condition.	Tensile Strength Pounds sq. in.	Indicated Endurance Limit Pounds sq. in.	% Ratio Endurance by Tensile Strength.	Surface Finish.
1.	Annealed	84,000	50-55,000	59-65	No. 4
2.	Cold rolled 10 per cent.	96,000	65-70,000	68-73	No. 4
3.	Annealed	75,000	22-24,000	29-32	No. 2-B
4.	Annealed	89,000	32-34,000	36-38	No. 2-B
5.	Cold rolled 50 per cent.	158,000	53-58,000	33-37	No. 2-B
6.	Cold rolled	180,000	70-74,000	39-41	Rolled
7.	Cold rolled and aged	194,000	75-81,000	39-42	No. 2-B
8.	Cold rolled 50 per cent.	195,000	63-78,000	32-40	No. 2-B
9.	Aged	243,000	—	—	Rolled

The S-N data so obtained indicate the probable endurance limits but are incomplete because of lack of time for aluminium alloys and the scatter of results for many of the stainless steels. The ratio of endurance limit to tensile strength of the stainless steels was found to be relatively constant for one type of surface condition but to change a maximum of from 30 to 70 per cent. with different commercial finishes. Errors considered were mechanical or inherent in the test method; i.e., increases of stress at constant deflection near the endurance

limit accompanied by plastic behaviour resulted from work hardening or decreases in apparent stress from crack formation and propagation, particularly in Alclad. The effects of the two opposing factors, work hardening and cracking, were studied by means of damping and mechanical hysteresis (load-bending) tests on actual fatigue specimens at various intervals during stressing above and near the endurance limit. Very considerable changes took place in Alclad specimens but changes in the stainless steels were relatively slight although considerable differences were found among the various types studied

Low Amperage Electronic Arc Welding. (D. B. Scott, Welding Engineer, Vol. 26, No. 7, July, 1941, pp. 21-24.) (96/47 U.S.A.)

The electronic welder produces a direct current output at the welding terminals, though it is operated from a three-phase alternating current source. Output characteristics are such that a stable arc can be held at any setting to supply welding currents from 5 amperes to 75 amperes, thereby providing for the welding of materials from 32 gauge to 10 gauge with equal ease and success.

The following Table shows etectrode diameter versus welding current and material gauge:—

ELECTRODE SIZES FOR VARIOUS CURRENTS AND MATERIAL THICKNESSES.

Electrode Diameter.	Welding Current Amperes.	Thickness Material to be Welded.
1/32 in.	5 to 10	32 to 26 gauge
3/64 in.	10 to 20	26 to 20 gauge
1/16 in.	20 to 40	20 to 14 gauge
3/32 in.	40 to 60	14 to 10 gauge
1/8 in.	60 to 75	10 to 1/4 in.

Low current arc welding equipment has made possible the arc welding of all types of aircraft tubing and has been approved by the Army and Navy Air Corps and the Civil Aeronautics Administration, U.S.A., subject only to the qualification of the welding operators. It has cut the necessary welding time in certain cases to as much as one quarter of that required by previous methods.

Other products in the aircraft field which have been improved by the introduction of low current arc welding are the collector rings, exhaust manifolds, air to air heat exchangers for cabin heating, and exhaust manifold shrouds. These parts are usually made from Inconel or a heat-resisting stainless alloy such as 25 Cr-20 Ni, and are made from matching half sections that are welded together.

The Stresses in and the Deflection of Circular Flat Plates, with a Central Hole Under Normal Force. (S. Labrow, Procs. Inst. Mech. Engs., Vol. 145, No. 3, June, 1941, pp. 115-125.) (96/48 Great Britain.)

Solutions are given, and presented in graphical form, for the stresses in, and the deflection of, a thin circular plate when loaded by normal (transverse) forces only, with various prescribed conditions of supporting or fixing the edges.

The method used in deriving these results is an application of a general method for obtaining the direct and, or alternatively, the bending stresses in a thin circular plate under any type of loading. Because of the ease with which it can be applied to problems in which the loading on the plate is quite complex, this general method, due to Professor William Kerr, deserves to be more widely known, and a brief account of it is given by the author as an introduction to the special problem with which the paper is primarily concerned.

Kerr has shown that provided certain conventional forms are chosen to express the external forces on the disk—whether these are due to normal pressure (transverse) loading, to radial loading (as in a rotating disk), or to temperature differences giving rise to either transverse or radial temperature gradients and

stresses, then the fundamental equations for the disk under the most general type of loading can be considerably simplified. Briefly, this simplification consists in a division of these equations into two groups, one of which contains only the " bending stress " terms, whilst the other group contains only the " direct " or " Membrane " stress terms. The feature of Kerr's method is that these two groups are absolutely identical in form, due to the conventional forms which are chosen to represent the external forces, and thus it is only necessary to obtain the solution of one group. As would be expected, the resulting general solution possesses a high degree of symmetry and is particularly well suited to presentation in tabular form, from which expressions for the stresses for simple and complex loading conditions can be written down immediately.

The author has applied Kerr's method to obtain the solution of one type of example which finds frequent application in many engineering problems. This is the case of a disk, with a central hole, and loaded by transverse forces. In all, twelve variations, representing different edge conditions and different loading have been investigated, each covering a range of disk proportions. The results of this analysis are presented in the form of tables and curves and illustrate the usefulness of Kerr's method in solving problems of this sort.

The Relationship Between Stress and Strain in the Tensile Impact Test. (A. F. C. Brown and N. D .G. Vincent, Proc. Inst. Mech. Eng., Vol. 145, No. 3, June, 1941, pp. 126-134.) (96/49 U.S.A.)

In impact testing, the notched bar test is that most frequently used and is valuable for the detection of brittleness; but the notch introduces an extremely complicated stress system and, despite frequent discussions, no universal agreement has been reached as to the method of test or form of specimen. The static tensile test, on the other hand, has been fully investigated and test bars of widely different sizes can be relied on to give comparable results.

Apparatus has been devised for the measurement of the relationship between stress and strain on metallic specimens broken in tensile impact. The stress was measured piezo-electrically and the strain photo-electrically.

Five ferrous materials have been examined at rates of extensional strain ranging up to 800 inches per inch per second, with the following results:—

With wrought iron there was an increase in tensile strength and considerable increase in yield point as the rate of strain was raised. With medium-carbon steel there was some increase in the yield point. With low-carbon manganese steel, nickel-chromium steel and " Vibrac " steel there was little difference between the impact and static stress-strain diagrams. The energy absorbed in fracture of the specimens in the impact tests was only slightly greater than that absorbed in the static tests.

On the whole, the measurements of impact stress bear out the results of earlier investigators. Some increase in ultimate stress had been expected with materials besides wrought iron but, after careful examination of the results, the authors cannot find any evidence for increase except for this one material.

Spot Welding of Light Alloys. (Junkers Journal, Vol. 12, No. 5-6, May-June, 1941, pp. 59-69.) (96/50 Germany.)

Spot welding of light alloy sheets has been successful, provided proper attention is paid to the preliminary treatment of the sheet and that the welding current and elecrode pressures are suitable. Pure Al, Al-Mg, and Al-Si-Mg Alloys are relatively easy to spot weld, although in the latter case, the heat treated material will lose some of its strength in the weld zone. Al-Cu-Mg alloy sheet require the greatest care in the control of the current characteristics. Loss of strength due to softening can be made good by a closer spacing of the spots.

A thorough cleaning of the sheets prior to welding is essential. This can be carried out either by immersion in a caustic soda bath or by mechanical brushing.

As already mentioned, control of the welding current is of the utmost importance. Experiments were carried out with different types of current pulses and rest periods. An alteration of the wave form during the welding process was found to be beneficial.

Thus for example, a successful current control adopted consisted of 5 periods at maximum amplitude alternating with 5 periods at 50 per cent. amplitude with rest periods (zero current) of 5 periods between the changes (1 period = 1/50 sec.). In this case there are 2 pulses per spot weld. Alternatively, single pulse control can be adopted, the current rising to a maximum during 5 periods and diminishing to zero over the next 5 periods. No details of the electronic controls are given. By proper timing of the pulses, it is apparently possible to work four or more machines from a single 350 K V A transformer, leading to a considerable saving in the cost of the plant. Types of electrodes employed are described in some detail. Electrolytic copper appears to be the most suitable material. Means for rapid cleaning of the electrodes are essential. Interposition of a thin foil of brass between electrode and weld has been found very beneficial in this connection. The foil (in ribbon form) is moved automatically and carries away most of the impurities which would otherwise accumulate on the electrode.

X-Ray Examination of Mg. Alloy Castings. (H. T. Rupprecht, Luftwissen, Vol. 8, No. 9, Sept., 1941, pp. 283-286.) (96/51 Germany.)

X-Ray examination of Mg Alloys is rendered difficult by the small absorption coefficient of the material coupled with a considerable amount of scattering of the radiation. The latter becomes the more marked, the shorter the wave length of the incident radiation, i.e. the higher the tube voltage. For work of this kind, therefore, it becomes necessary to generate X-Ray at relatively low voltage and ensure sufficient penetration by increasing the tube current. Unfortunately commercial X-Ray apparatus are generally designed for voltages of the order of 250 K V (20 m. Amp.) and cease to generate if the voltage is reduced below 50 K V. At the same time the tubes normally employed will not pass an increased current to make up for the voltage reduction. According to the author, special apparatus has now become available which will generate X-Rays at 24 K V (4 m. Amp.) and pass 30 m. at 100 K V. With this equipment, examination of Mg alloys can be carried out with the same degree of accuracy as for Al. alloys. The new apparatus is, however, necessarily expensive and can only justify itself if exclusively and continuously employed on Mg alloys. As an alternative, quite good results can be obtained with standard equipment if a special photographic film of ultra fine grain and steep gradation is employed. The new film is relatively insensitive to scattered radiation and its superiority in detecting faults is illustrated by a number of sample photographs.

Evidence on the State of Fatigue of Metals Obtained by Determination of Surface Stresses by Means of X-Rays. (R. Glocker and others, Z.V.D.I., Vol. 85, No. 39-40, 4/10/41, pp. 793-800.) (96/53 Germany.)

The measurement of surface stresses by X-Ray methods depends on the fact that the dimensions of the Debye diffraction rings are directly related to the elastic deformation of the crystal structure of the materials. Up to now, such investigations have been mainly confined to the investigation of static stress. The authors describe a most ingenious camera in which the photographic film rotates in step with a tortion fatigue testing machine and which makes possible the measurement of the variation of surface stress during a complete load cycle. It appears that the proportion of the total stress taken up elastically by the surface layer of the metal diminishes progressively with total number of load cycles and by using X-Rays of different hardness the authors show that in the case of carbon steel, this plastic deformation is gradually penetrating into the material core. The authors were thus able to predict the state of fatigue

of the material from X-Ray examination of samples subjected to static load. Of great importance is the fact that the appearance of the first cracks in the specimen is revealed by X-Ray examination at a relatively early state (60 per cent. of the ultimate life). Such small cracks cannot be detected by any other method. The magnetic powder method only reveals much larger cracks occurring when already 85 to 90 per cent of the load cycles required for ultimate failure have been reached.

The Calculation of the Load Capacity of Ball and Roller Bearings. (R. Mundt, Z.V.D.I., Vol. 85, No. 39-40, 4/10/41, pp. 801-806.) (96/54 Germany.)

The load capacity and life of ball and roller bearings are matters of great importance. The author reviews the data given by a number of leading German manufacturers for their products over the period 1903 to date. (D.W.F., F. & S., F.A.G. and S.K.F.) The theoretical basis of calculations on load capacity and life are next reviewed and the importance of standardisation in this field is stressed.

In modern engineering, indefinite life is scarcely an economic proposition. In most cases, the machine incorporating ball or roller bearings is scrapped for various reasons after a relatively short life. The load capacities of bearings as given by the different manufacturers for their products generally imply that most of the bearings will have a much longer life than the limits stated. A standard method of calculation would enable the user to select more readily the bearing satisfying his minimum demands.

Aircraft Materials—German Specification Numbers. (R. Liebig, Werkstoffkunde, pp. 94-98.) (96/55 Germany.)

All German specification numbers for aircraft materials consist of 4 figures followed by a decimal point and a fifth figure, e.g. 3,166.5.

In this code, the first figure denotes the principal group to which the material belongs, e.g. 1 = steel, 2 = non-ferrous heavy alloy, 3 = light alloy, etc.

The second figure in the code shows a sub-group in the principal group, whilst the last two figures before the decimal point are called the material numbers and designate the material more closely. The figure behind the decimal point so-called condition number, finally shows the treatment to which the semi-finished product has been subjected prior to delivery to the consumer.

The meaning of some of the code numbers is given in the tables below:—

Principal Group.	Sub-Group.	Significance.
1 = Steels	0	Carbon steels, not improved by heat treatment.
	1	Carbon steels, improved by heat treatment.
	2	Simple Alloy Steels.
	3	Multiple Alloy Steels.
	4	Special Steels.
	5	
	6	
	7	
	8	Cast Steel.
	9	Cast Iron.
2 = Heavy Alloys	0	Copper.
	1	Brass.
	2	Special Brass.
	3	Al/Pb Bronze.
	4	Special Bronze.
	5	White Metal.

Principal Group.	Sub-Group.	Significance.
3=Light Alloys	0	Pure Al.
	1	Dural.
	2	Al-Si (Silumin).
	3	Al-Mg (Hydronalium). Al-Mg-Si (Legal)
	4	Other Al Alloy.
	5	Mg Alloy.

Sub-Group.	M.N.	Significance.
0	00	Al 99.5 per cent.
1	15	Dural (Normal).
1	16	Cladded Dural.
1	30	Alloy RR 53 (sand cast).
1	31	,, die cast.
1	35	Y alloy, sand cast.
1	36	,, die cast.
1	37	,, extruded or forged.
2	00	Silumin, sand cast.
2	01	Copper Silumin, die cast.
2	05	Silumin—Beta, sand cast.
2	10	E.C. 124 die cast.
2	11	E.C. 124 pressed.
2	15	Alusil, KS 280 die cast.
3	05	Hydronalium Hy 5
3	10	,, Hy 7.
3	15	,, Hy 9.
3	55	Legal.
5	01	Electron A.M. 503.
5	10	Electron A.2.M.

Note: An increase in M.N. in any sub-group signifies improved mechanical properties.

Condition Numbers (after decimal point).

Principal Group.	C.N.	Significance.
1 Steels	0	No subsequent treatment.
	1	Annealed.
	2	,,
	3	,,
	4	,,
	5	Hardened or heat treated.
	6	,, ,,
	7	Cold worked.
	8	,,
	9	Specially treated.
2 Heavy Alloys	0	No subsequent treatment.
	1	Annealed.
	2	—
	3	—
	4	Heat treated.
	5	,, and cold worked.
	6	,, ,,
	7	Cold worked.
	8	,,
	9	Specially treated.

Principal Group.	C.N.	Significance.
3=Light Alloys	0	No subsequent treatment.
	1	Annealed.
	2	Annealed and straightened.
	3	—
	4	Age hardened.
	5	Age hardened and straightened.
	6	Age hardened and cold worked.
	7	Cold worked.
	8	,,
	9	Specially treated.

The code number 3116.5 given above thus refers to Cladded Dural (Al-Cu-Mg alloy with Al covering sheet) age hardened and straightened.

LIST OF SELECTED TRANSLATIONS.

No. 39.

NOTE.—Applications for the loan of copies of translations mentioned below should be addressed to the Secretary (R.T.P.3), Ministry of Aircraft production, and not to the Royal Aeronautical Society. Copies will be loaned as far as availability of stocks permits. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

ARMAMENT AND WARFARE.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND JOURNAL.
1289	Tsaig, M.	*Barrage Balloons.* (Aeroplane, U.S.S.R., Vol. 17, No. 23-24, Dec., 1940, p. 22.)
1293	Pugatchev, V. S. ... Blinov, B. K. ...	*Calculation of Ballistic Elements for Firing in the Air.* (Air Fleet News, U.S.S.R., Vol. 23, No. 2, Feb., 1941, pp. 129-138.)
1307	Beseler, J.	*British Aircraft Armament Through German Eyes.* (Luftwissen, Vol. 8, No. 8, Aug., 1941, pp. 237-243.)

AERODYNAMICS AND FLIGHT DYNAMICS.

1280	Stiiper, J.	*The Measuring Technique of Flight Tests.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 109-113.)
1304	Schmidt, R. ...	*Systematic Flight Tests on Dynamic Longitudinal Stability with Free Elevator.* (L.F.F., Vol. 18, No. 5, 28/5/41, pp. 169-173.)
1311	Eugen, J.	*Some Remarks on Statical and Dynamical Longitudinal Stability.* (Luftwissen, Vol. 8, No. 4, April, 1941, pp. 119-125.)
1313	Mathias, G. ... ... Schaaf, R.	*Landing Process (Length of Run, Braking Effort and Possibility of Tipping.* (L.F.F., Vol. 18, No. 2-3, 29/3/41, pp. 70-76.)

Aircraft and Accessories.

TRANSLATION NUMBER AND AUTHOR.		TITLE AND JOURNAL.
1281	Yegorov	*Oxygen Equipment of German Aircraft.* (Air Fleet News, U.S.S.R., Vol. 23, No. 5, May, 1941, pp. 448-455.)
1282	Podlubinaya, E. T.	*Cheap Solutions for Washing Aircraft.* (Civil Aviation, U.S.S.R., Vol. 11, No. 5, May, 1941, p. 15.)
1288	Shavrov, V.... ...	*The U.S.S.R. Amphibian "Sh. 7."* (Aeroplane, U.S.S.R., Vol. 17, No. 23-24, Dec., 1940, p. 22.)
1290	Bleich, H. S. ...	*On the Calculation of Variable Aperture Shock Absorbers.* (Aeron. Eng., U.S.S.R., Vol. 15, No. 4, April, 1941, p. 57.)
1291	Pelix, N. A. ...	*Tolerances in Undercarriage Links.* (Aviation Industry, U.S.S.R., Vol. 1, No. 17, May, 1941, pp. 8-10.)
1292	Kostyuk, D. I. ...	*Kinematics of the Retractable Undercarriage.* (Aeron. Eng., U.S.S.R., Vol. 15, No. 3, March, 1941, pp. 53-55.)

Engines and Accessories.

1285	Stepukhin, Z. A. ...	*Methods for Counteracting Corrosion of Pipes in Water-Cooled Aero Engines.* (Aviation Ind., U.S.S.R., Vol. 1, No. 6, Feb., 1941, pp. 7-11.)
1295	Ananiev and others	*Calculation of Resonance Vibrations of Elastically Supported Engine Mountings.* (Aeron. Eng., U.S.S.R., Vol. 15, No. 4, April, 1941, pp. 21-40.)
1306	Preitz	*The Warming up of Aircraft Engines.* (Der Flieger, Vol. 20, No. 5-6, May-June, 1941, pp. 188-190.)

Materials and Elasticity.

1294	Erlinger, E. ...	*Fatigue Testing Machines for Large Specimens.* (Luftwissen, Vol. 18, No. 6, June, 1941, pp. 177-181.)
1305	—	*Weldability and Crack Sensitivity of Steel.* (Digest of Articles from Z. fur Mechanik, Vol. 10, No. 3, pp. 115-117.)
1312	Cornelius, R. ...	*On the Stability of Heat Resisting Materials for Internal Combustion Engines.* (L.F.F., Vol. 18, No. 8, 20/8/41, pp. 289-304.)

Miscellaneous.

1283	Rozhdestvin, N. P....	*Aerial Photography in Colour.* (Air Fleet News, U.S.S.R., Vol. 23, No. 4, April, 1941, pp. 333-335.)
1296	Guglielmetti, A. ...	*Lines of Development of Italian Aircraft.* (Luftwissen, Vol. 8, No. 7, July, 1941, pp. 209-215.)

TITLES AND REFERENCES OF ARTICLES AND PAPERS SELECTED FROM PUBLICATIONS RECEIVED IN R.T.P.3 DURING OCTOBER, 1941.

Notices and abstracts from the Scientific and Technical Press are prepared primarily for the information of Scientific and Technical Staffs. Particular attention is paid to the work carried out in foreign countries, on the assumption that the more accessible British work (for example, that published by the Aeronautical Research Committee) is already known to these Staffs.

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44	29390	U.S.A. ...	*The Chemical Warfare Service in National (U.S.A.) Defence.* (W. N. Porter, Ind. and Eng. Chem. (News Ed.), Vol. 19, No. 18, 25/9/41, pp. 1,025-1,027.)
45	29393	U.S.A. ...	*B.17 Flying Fortress.* (Trade Winds, Sept., 1941, pp. 2-5 and 18.)
46	29405	Great Britain	*The Russian Air Force.* (The Engineer, Vol. 172, No. 4,478, 7/11/41, p. 314.)
47	29411	Germany ...	*U.S.S.R. Single-Seat Fighter 1-16 (with Photograph).* (Flugsport, Vol. 32, No. 26, 18/12/40, pp. 448-449.)
48	29412	Germany ...	*Suggested Designs for Twin-Engined Fighters.* (Flugsport, Vol. 32, No. 26, Dec. 18th, 1940, pp. 450-451.)
49	29413	Germany ...	*Some British Patents on Remotely Controlled Aircraft Guns.* (Flugsport, Vol. 32, No. 26, 18/12/40, pp. 454-455.)
50	29421	Germany ...	*Cartridge Box for Wing Guns (Patent No. 699,414).* (Patent Collection, No. 39, Arado, Flugsport, Vol. 32, No. 26, 18/12/40, p. 60.)
51	29424	Germany ...	*Retractable Undercarriage Details of Heinkel He. 111, F.W. 200 and Ar. 79.* (Wissen und Fortschritt, Vol. 15, No. 8, Aug., 1941, pp. 418-419.)

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52	29431	U.S.A. ...	*Japanese Air Power.* (L. Zacheroff, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 48-49 and 146-150.)
53	29438	U.S.A. ...	*Messerschmitt Me. 110C (Sectional Drawings).* (Aviation, Vol. 40, No. 9, Sept., 1941, p. 79.)
54	29439	U.S.A. ...	*Landing Gear Mechanism of Boeing Flying Fortress.* (Aviation, Vol. 40, No. 9, Sept., 1941, p. 81.)
55	29441	U.S.A. ...	*D.G.A.-160 Advance Trainer (Howard).* (Aviation, Vol. 40, No. 9, Sept., 1941, p. 91.)
56	29464	Great Britain	*Handley Page "Halifax" in Service.* (Flight, Vol. 40, No. 1,715, 6/11/41, pp. 322-324.)
57	29466	Great Britain	*Equivalent Ranks in Allied Air Forces.* (Flight, Vol. 40, No. 1,715, 6/11/41, p. 330.)
58	29467	U.S.A. ...	*Douglas Boston III (Photograph).* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, p. 499.)
59	29469	Great Britain	*Northrop Experimental Tail-less Fighter (Photograph).* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, p. 501.)
60	29470	Great Britain	*Handley Page "Halifax."* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, pp. 506-507.)
61	29471	Germany ...	*German Aeroplanes in Service (XI) (Gotha and Heinkel Series).* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, p. 509.)
62	29484	Germany ...	*Soviet Aircraft Types (J.15, J.153, J.16, S.B.2, S.B.3 and D.B.3).* (Flugsport, Vol. 33, No. 15, 23/7/41, pp. 293-298.)
63	29485	Italy	*Cant. Z. 1007 bis Bomber.* (Flugsport, Vol. 33, No. 16, 6/8/41, pp. 317-319.)
64	29493	Germany ...	*Aircraft Machine Gun Mounting (Patent No. 708,025).* (M.W.N. (Patent Collection, No. 10.) Flugsport, Vol. 33, No. 16, 6/8/41, pp. 38-39.)
65	29508	Japan ...	*Mitsubishi 92 Bomber (Photograph).* (Aeroplane, Vol. 61, No. 1,590, 14/11/41, p. 531.)
66	29509	Great Britain	*Avro "Manchester."* (Aeroplane, Vol. 61, No. 1,590, 14/11/41, p. 541.)
67	29511	Germany ...	*German Aeroplanes in Service (XII) (Heinkel Series).* (Aeroplane, Vol. 61, No. 1,590, 14/11/41, p. 549.)
68	29513	Germany ...	*Me. 109 Camouflaged for Desert Warfare (Photograph).* (Flight, Vol. 40, No. 1,716, 13/11/41, p. 333.)
69	29517	Great Britain	*Avro "Manchester" Heavy Bomber.* (Flight, Vol. 40, No. 1,716, 13/11/41, pp. 339-341.)
70	29527	Germany ...	*Photographic Reconnaissance (Illustrated).* (Luftwelt, Vol. 8, No. 19, 1/10/41, pp. 364-375.)
71	29550	Germany ...	*Arado AR96B (Trainer).* (Flugsport, Vol. 32, No. 12, 5/6/40, pp. 165-167.)
72	29551	U.S.A. ...	*U.S.A. Stearman X100 (XA-21) Bomber.* (Flugsport, Vol. 32, No. 12, 5/6/40, p. 167.)
73	29552	U.S.A. ...	*U.S.A. Grumman F_3F-3.* (Flugsport, Vol. 32, No. 12, 5/6/40, p. 168.)
74	29554	Germany ...	*Ju. 52 Ambulance Plane.* (Flugsport, Vol. 32, No. 12, 5/6/40, p. 169.)
75	29559	Germany ...	*Container for Flares Carried on Aircraft* (689,843). (Henschel (Pat. Coll. No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 106.)

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76	29561	Germany ...	*Automatic Anchor for Stopping Drift of Supplies Dropped by Parachute* (689,844). (Autoflug (Pat. Coll. No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 108.)
77	29562	Germany ...	*Improvement in Smoke Signals* (689,791). (Ferstel (Pat. Coll. No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 108.)
78	29564	Italy	*Italian F.S. Single-Seat Fighter with Fiat A.74, R.C. 38.* (Flugsport, Vol. 32, No. 14, 3/7/40, pp. 201-202.)
79	29565	Germany ...	*Arado AR.196 Coastal Reconnaissance (Photograph).* (Flugsport, Vol. 32, No. 14, 3/7/40, p. 203.)
80	29574	Great Britain	*British Two-Seater Hawker "Hotspur" Fighter (Photograph).* (Flugsport, Vol. 32, No. 15, 17/7/40, pp. 222-223.)
81	29579	Germany ...	*Incendiary Leuf (Photograph).* (Flugsport, Vol. 32, No. 20, 25/9/40, p. 317.)
82	29586	Germany ...	*Some Notes on Repair and Maintenance at an Advance German Air Base in Sicily.* (Junkers Journal, Vol. 12, No. 5-6, May-June, 1941, pp. 70-72.) (Abstract available.)
83	29596	Great Britain	*American Views on Air Force Control by the Army.* (Flight, Vol. 40, No. 1,717, 20/11/41, pp. 356-357.)
84	29598	Great Britain	*Asbestos Suits for Fire Rescues.* (Flight, Vol. 40, No. 1,717, 20/11/41, p. h.)
85	29599	Great Britain	*"Manchester" Squadron.* (Flight, Vol. 40, No. 1,717, 20/11/41, pp. 352, 359-361.)
86	29600	Great Britain	*Bristol Hydraulically Operated Gun Turrets.* (Flight, Vol. 40, No. 1,717, 20/11/41, pp. 362-364.)
88	29614	Great Britain	*Spitfire V (Two Cannons and Four Machine Guns) (Photograph).* (Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 306 and 318.)
89	29615	Great Britain	*Hurricane IIb and IIc (Four Cannon or Twelve Machine Guns) (Photograph).* (Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 307 and 318.)
90	29616	Great Britain	*American Notes on the Mc.* 110. (J. C. Thompson, Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 308-310.)
91	29623	Germany ...	*Ju.* 88 *Bomber.* (Flugsport, Vol. 33, No. 22, 29/10/41, pp. 430-434.)
92	29624	Germany ...	*Personal Equipment of Air Crew Carrying Out Enemy Raids.* (Flugsport, Vol. 33, No. 22, 29/10/41, pp. 434-435.)
93	29627	Germany ...	*Anti-Dazzle Device for Glass Cockpits* (711,793). (Heinkel (Pat. Coll. No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 57.)
94	29643	Great Britain	*Vulnerability of Aircraft Carriers.* (Aeroplane, Vol. 61, No. 1,591, 21/11/41, pp. 554-555.)
95	29644	Great Britain	*Cable Fenders for Aeroplanes.* (Aeroplane, Vol. 61, No. 1,591, 21/11/41, pp. 556.)

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96	29645	Great Britain	*Bristol Turrets.* (Aeroplane, Vol. 61, No. 1,591, 21/11/41, pp. 562-563.)
97	29646	Great Britain	*Avro "Manchester" I.* (Aeroplane, Vol. 61, No. 1,591, 21/11/41, pp. 564-565.)
98	29647	Germany ...	*German Aeroplanes in Service (XIII) (Heinkel Series).* (Aeroplane, Vol. 61, No. 1,591, 21/11/41, p. 573.)
99	29651	Great Britain	*Development of Bristol Aircraft Gun Turrets.* (Engineer, Vol. 172, No. 4,480, 21/11/41, pp. 357-358.)
100	29661	U.S.A. ...	*Gun Installation in Hurricane II (Photograph).* (Autom. Ind., Vol. 85, No. 8, 15/10/41, p. 44.)
102	29674	U.S.A. ...	*Bullet-Sealing Hose Pipe for Combat Planes.* (Sci. Amer., Vol. 165, No. 5, Nov., 1941, pp. 249-250.)
103	29676	U.S.A. ...	*Value of Black-Out as a Means of A.A. Defence Questioned.* (Sci. Amer., Vol. 165, No. 5, Nov., 1941, p. 250.)

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104	29280	U.S.A. ...	*Wright Field New 20 ft. Wind Tunnel.* (Aero Digest, Vol. 38, No. 4, April, 1941, p. 140.)
105	29386	Great Britain	*Characteristics of Fire Jets (Discussion and Errata).* (J. S. Blair, J. Inst. Civ. Engs., Vol. 16, No. 8, Oct., 1941, pp. 597-599.)
108	29392	Great Britain	*A Method for Making Streamlines Momentarily Visible by Means of Phosphorescent Zinc Sulphides.* (A. M. Binnie and E. J. Bowen, Procs. Camb. Phil. Soc., Vol. 37, Pt. 4, 1941, pp. 436-437.)
109	29488	Germany ...	*Some Modern Views on Atmospheric Turbulence and Sailing Flight.* (H. Trick, Flugsport, Vol. 33, No. 16, 6/8/41, pp. 332-334.)
110	29503	Great Britain	*Distribution of Velocity Within a Nest of Tubes.* (R. P. Wallis, Engineering, Vol. 152, No. 3,956, 7/11/41, pp. 361-363.)
111	29519	Japan ...	*The Characteristics of the Aerofoil with Discontinuities Along the Span, with Special Reference to the Effects of Cut-Out.* (T. Okamoto, Aero. Res. Inst., Tokyo, No. 208, May, 1941, pp. 207-263.) (Abstract available.)
112	29542	Great Britain	*The Friction and Heat Transmission Coefficients of Rough Pipes.* (W. F. Cope, Procs. Inst. Mech. Engs., Vol. 145, No. 3, June, 1941, pp. 99-105.) (Abstract available.)
113	29592	Germany ...	*The Aerodynamics of Animal Flight.* (D. Kuchemann and E. Holst, Luftwissen, Vol. 8, No. 9, Sept., 1941, pp. 277-282.)
114	29609	Great Britain	*The Shape of a Liquid Jet as a Graphical Solution of Bernoulli's Equation.* (J. M. A. Leniham, Phil. Mag., Vol. 32, No. 214, Nov., 1941, pp. 393-400.)

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115	29025	Germany ...	*Contribution to the Problem of Oscillating Wing Flight.* (Flugsport, Vol. 33, No. 22, 29/10/41, pp. 435-438.)
117	29665	U.S.A. ...	*On the Statistical Theory of Turbulence.* (C. L. Pekeris, J. Aeron. Sci., Vol. 8, No. 12, Oct., 1941, pp. 475-476.) (Abstract available.)
118	29667	Germany ...	*The Development of the Cowled Propeller for Ship Propulsion.* (Z.V.D.I., Vol. 85, No. 39-40, 4/10/41, p. 812.)
119	29689	Germany ...	*A Method for Calculating the Theoretical Characteristics of Turbo Machines (Rotating Blade Systems).* (G. Klingemann, Ing. Arch., Vol. 11, No. 3, June, 1940, pp. 151-178.)
120	29691	Germany ...	*The Hydrodynamic Theory of Bearing Friction.* (R. Nature, Ing. Arch., Vol. 11, No. 3, June, 1940, pp. 191-209.)
			AIRCRAFT AND AIRSCREWS.
121	29231*	Great Britain	*Wing Weight Estimations.* (C. R. Engleberry, Flight, Vol. 40, No. 1,714, 30/10/41, pp. 301-304.)
122	29237	Great Britain	*A Note on the Limitation of Aircraft and Aerofoils Used for High Flying Aircraft.* (J. A. C. Williams, J. Roy. Aeron. Soc., Vol. 45, No. 370, Oct., 1941, pp. 323-325.)
123	29240	U.S.A. ...	*Salvage Operation on Aeroplanes Embedded in Ice.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 53, 223.)
124	29241	U.S.A. ...	*Simple Cockpit Arrangement Needed.* (F. Smith, Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 54.)
125	29242	U.S.A. ...	*Standard Runway Marking.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 58.)
126	29243	U.S.A. ...	*Low Cost Bases for Seaplanes.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 59 and 61.)
127	29244	U.S.A. ...	*Master Plan for Airport Development.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 60-61.)
128	29246	U.S.A. ...	*Modern Hangar Door Design (Canopy Type).* (J. I. Byrne, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 80-82.)
129	29247	U.S.A. ...	*Flotation Fueling System for Airport.* (A. C. Kaestner, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 80-86.)
130	29248	U.S.A. ...	*Speed in Concrete Airport Paving.* (A. A. Anderson, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 88-90, 230-231.)
131	29249	U.S.A. ...	*A Design for the Airport of To-morrow.* (A. Andrews, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 92-94.)
132	29250	U.S.A. ...	*The Airport Programme of the C.A.A.* (D. H. Connolly, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 571-594.)
133	29251	U.S.A. ...	*The Dual Role of the Airport (Civil and Military).* (J. W. Wood, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 97-98, 224.)

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134	29252	U.S.A. ...	*General Design and Materials Used in Hangar Construction.* (E. K. Harvey, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 101-104.)
135	29253	U.S.A. ...	*Fuel Dispensing System for Airports.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 195.)
137	29258	U.S.A. ...	*Aircraft Cost Control.* (G. M. Giannini, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 187-189 and 192.)
138	29263	U.S.A. ...	*Advantages of the New Explosive Rivets.* (D. L. Lewis, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 183 and 228.)
139	29264	U.S.A. ...	*Flat, Extended Tread Aircraft Tyres for Soft Ground Operation.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 195-196.)
140	29273	U.S.A. ...	*Balancing Aircraft Propellers (III).* (M. C. Beebe, Aero Digest, Vol. 38, No. 4, April, 1941, pp. 102-109, 193-194.)
141	29279	U.S.A. ...	*Socket Head Cap Screw (Design Applications).* (W. C. Stauble, Aero Digest, Vol. 38, No. 4, April, 1941, pp. 136-139.)
142	29300	Germany ...	*Savoia-Marchetti S.M.87 Transport Plane.* (Flugsport, Vol. 32, No. 13, 19/6/40, pp. 182-183.)
143	29301	Germany ...	*Block 161 Four-Engined Transport Plane (French).* (Flugsport, Vol. 32, No. 13, 19/6/40, pp. 183.)
144	29302	Germany ...	*Effect of Surface Roughness on Profile Characteristics (Mainly Based on N.A.C.A. Results).* (Profit Notes, No. 21, Flugsport, Vol. 32, No. 13, 19/6/41, pp. 81-84.)
145	29309	Germany ...	*Arrangement for Jettisoning Rear Portion of Fuselage for Quick Egress of Aircraft Crew (Patent 694,019).* (Patent Collection, No. 32, Messerschmitt, Flugsport, Vol. 32, No. 18, 28/8/40, p. 125.)
146	29310	Germany ...	*Boundary Layer Control by Suction (Patent 693,398).* (Patent Collection, No. 32, Junkers, Flugsport, Vol. 32, No. 18, 28/8/40, p. 125.)
147	29311	Germany ...	*Elastic Wing Root Fairings (Patent No. 694,021).* (Patent Collection, No. 32, Messerschmitt, Flugsport, Vol. 32, No. 18, 28/8/40, p. 126.)
148	29312	Germany ...	*Mass Balance of Control Surface (Patent No. 693,900).* (Patent Collection, No. 32, Heinkel, Flugsport, Vol. 32, No. 18, 28/8/40, p. 126.)
149	29313	Germany ...	*Pipe Joints with Conical Screw Threads (Patent No. 692,061).* (Patent Collection, No. 32, Junkers, Flugsport, Vol. 32, No. 18, 28/8/40, p. 127.)
150	29315	Germany ...	*Slotted Flaps (Patent No. 693,899).* (Patent Collection, No. 32, Focke-Wulf, Flugsport, Vol. 32, No. 18, 28/8/40, p. 125.)
151	29320	U.S.A. ...	*Cold Proof Neoprene Tyre F.R.* (Autom. Ind., Vol. 85, No. 6, 15/9/41, p. 39.)
152	29324	Great Britain	*Electric Power in Aircraft, III.* (J. B. Holliday, Aeroplane, Vol. 61, No. 1,587, 24/10/41, pp. 454-455.)

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153	29327	Germany	...	*High Speed Profiles* (*Profile Note No. 22*). (Flugsport, Vol. 32, No. 16, 31/7/40, pp. 85-88.)
154	29328	Germany	...	*Universal Joints of Ball and Socket Type* (*Eckelt*). (Flugsport, Vol. 32, No. 16, 31/7/40, p. 238.)
155	29332	Germany	...	*Transparent Plastic Shells for Aircraft* (*Self-Supporting*) (*Patent No.* 693,159). (Patent Collection, No. 30, Junkers, Flugsport, Vol. 32, No. 16, 31/7/41, p. 117.)
156	29333	Germany	...	*Reduction of Resistance at Supersonic Speeds by Boundary Layer Suction* (*Patent No.* 693,574). (Patent Collection, No. 30, Arado, Flugsport, Vol. 32, No. 16, 31/7/40, p. 118.)
157	29351	U.S.A.	...	*Proposed Changes in the C.A.A. Regulations for Wheel Brakes.* (Aero Digest, Vol. 38, No. 3, March, 1941, p. 114.)
158	29354	U.S.A.	...	*Private and Commercial Aircraft of the U.S.A.* (*Technical Digest*). (Aero Digest, Vol. 38, No. 3, March, 1941, pp. 139-162, 198-200.)
159	29362	U.S.A.	...	*Balancing Aircraft Propellers, II.* (M. C. Beebe, Aero Digest, Vol. 38, No. 3, March, 1941, pp. 256-260 and 272.)
160	29363	U.S.A.	...	*Automatic Cable Tension Regulator for Aircraft Installations.* (Aero Digest, Vol. 38, March, 1941, p. 264.)
161	29364	U.S.A.	...	*Electrically-Controlled Landing Gear Tester.* (Aero Digest, Vol. 38, No. 3, March, 1941, p. 268.)
162	29383	U.S.A.	...	*Loose Objects in Cabin a Source of Danger during Violent Manœuvres.* (Civil Aeronautics J., Vol. 2, No. 18, 15/9/41, p. 236.)
164	29410	Germany	...	*Italian Sailplane Trainer Cat-15* (*with Photograph*). (Flugsport, Vol. 32, No. 26, 18/12/40, p. 448.)
165	29414A	Germany	...	*Multi-Engined Land Plane with Seaworthy Cabin which can be Jettisoned* (*Patent* 699,351). (Patent Collection, No. 39, Henschel, Flugsport, Vol. 32, No. 26, 18/12/40, p. 157.)
166	29415	Germany	...	*Cockpit Covering-Constructional Features* (*Patent No.* 699,065). (Patent Collection, No. 39, Henschel, Flugsport, Vol. 32, No. 26, 18/12/40, p. 154.)
167	29416	Germany	...	*Folding Seats for Aircraft* (*Patent No.* 699,106). (Patent Collection, No. 39, Henschel, Vol. 32, No. 26, 18/12/40, pp. 157-158.)
168	29418	Germany	...	*Zigzag Wing with Engine Installed Inside Wing at the Vertices* (*Patent No.* 699,412). (Patent Collection, No. 39, Messerschmitt, Flugsport, Vol. 32, No. 26, 18/12/40, p. 158.)
169	29419	Germany	...	*Reduction of Surface Friction of a Wing Surface by the Ejection of Air* (*Patent No.* 699,066). Patent Collection, No. 39, D.V.L., Flugsport, Vol. 32, No. 26, 18/12/40, p. 158.)
170	29420	Germany	...	*Safety Device in Aircraft Structural Parts to Prevent Aerodynamic Overload* (*Air Leaks or Ripping Panel*) (*Patent No.* 699,067). (Patent Collection, No. 39, Focke-Wulf, Flugsport, Vol. 32, No. 26, 18/12/40, p. 159.)

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171	29433	U.S.A. ...	*Standard and Modified Aeroplane Specifications Prepared by Special Engineering Staff at Lockheed.* (P. A. Peck and R. H. Robb, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 56-57 and 182-184.)
172	29435	U.S.A. ...	*Aeroplane Hydraulic Systems.* (E. M. Green, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 70-71, 152-156 and 162.)
173	29459	U.S.A. ...	*Martin 170 Flying Boat (XPB2M-1) (Photograph).* (Flight, Vol. 40, No. 1,715, 6/11/41, p. 310.)
174	29463	Great Britain	*Future of Civil Aviation.* (Flight, Vol. 40, No. 1,715, 6/11/41, pp. 318-321.)
175	29468	U.S.A. ...	*Fuselage Erection of the Fairey "Albacore" (Photograph).* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, p. 500.)
176	29474	Germany ...	*Pressure Cabins for High Altitude Aircraft (Patent No. 707,313).* (Henschel (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 33.)
177	29475	Germany ...	*Tailless Aircraft Design (Patent No. 707,463).* (Messerschmitt (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 33.)
178	29476	Germany ...	*Slotted Flap Mechanism (Patent No. 706,959).* (Dornier (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 33.)
179	29477	Germany ...	*Slotted Flap Mechanism (Patent No. 707,147).* (Dornier (Patent Collection, No. 9), Vol. 33, No. 15, 23/7/41, p. 34.)
180	29478	Germany ...	*High Lift Flap (Patent No. 707,054).* (Messerschmitt (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 34.)
181	29479	Germany ...	*Elastic Member to Prevent Overload on Flap (Patent No. 707,401).* (Focke-Wulf (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 34.)
182	29480	Germany ...	*Slot Width Control on Flap Mechanism (Patent No. 707,402).* (Focke-Wulf (Patent Collection, No. 9), Flugsport, Vol. 33, No. 15, 23/7/41, p. 34.)
183	29481	Germany ...	*Combined Flap and Aileron Mechanism (Patent No. 707,424).* (Arado (Patent Collection, No. 9), Vol. 33, No. 15, 23/7/41, p. 35.)
184	29483	Germany ...	*Automatic Trimming Device for Single or Multi-Engined Aircraft Operated by Wind Vane.* (Blohm and Vass, Flugsport, Vol. 33, No. 15, 23/7/41, pp. 35-36.)
185	29487	Germany ...	*Aircraft Design Features—Some Simple Examples of Saving Weight (Dornier).* (Flugsport, Vol. 33, No. 16, 6/8/41, pp. 321-324.)
186	29489	Germany ...	*Collapsible Seat for Aircraft (Prone Position) (Patent No. 708,248).* (Heinkel (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 37.)

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187	29490	Germany ...	*Increasing Effect of Spoiler for Lateral Control by Ejecting Air into Spoiler Wake* (*Patent No.* 707,868). (Goettingen Aerodynamic Laboratory (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, pp. 37-38.)
188	29491	Germany ...	*Vibration Damper for Control Surface and Flaps* (*Patent No.* 707,678). (Henschel (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 38.)
189	29492	Germany ...	*Damping Control Surfaces* (*Patent No.* 708,228). (Messerschmitt (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 38.)
190	29494	Germany ...	*Method of Connecting Badly Fitting Plates on Aircraft by Means of Special Bolt Plates* (*Patent No.* 708,105). (Messerschmitt (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 39.)
191	29495	Germany ...	*Helicopter Blade Incidence Control* (*Patent No.* 707,982). (German Govt. (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 39.)
192	29496	Germany ...	*Spring Control for Castoring Aircraft Tail Wheel* (*Patent No.* 706,961). (Fieseler (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 39.)
193	29497	Germany ...	*Leaf Springs for Undercarriage Legs* (*Patent No.* 708,026). (Mahle (Patent Collection, No. 10), Flugsport, Vol. 33, No. 16, 6/8/41, p. 39.)
194	29507	U.S.A ...	*Martin 170 Flying Boat.* (Aeroplane, Vol. 61, No. 1,590, 14/11/41, p. 529.)
195	29510	Great Britain	*Tailless Aircraft.* (Aeroplane, Vol. 61, No. 1,590, 14/11/41, pp. 542-545.)
196	29514	Great Britain	*Northrop Tailless Aircraft.* (Flight, Vol. 40, No. 1,716, 13/11/41, pp. 337-338.)
197	29525	Germany ...	*The Historical Development of the Junkers Single and Multi-Engined Transport Plane.* (Junkers Journal, Vol. 12, No. 1 and 2, Jan.-Feb., 1941, pp. 11-20.)
198	29548	Germany ...	*Boundary Layer Control by Suction.* (Messerschmitt (Pat. Coll., No. 26), Flugsport, Vol. 32, No. 11, 22/5/40, p. 102.)
199	29549	Germany ...	*Aileron Spoiler Combination for Lateral Control.* (Messerschmitt (Pat. Coll., No. 26), Flugsport, Vol. 32, No. 11, 22/5/40, p. 104.)
200	29553	Germany ...	*Project for 100-t Transatlantic Douglas (Six Engines).* (Flugsport, Vol. 32, No. 12, 5/6/40, pp. 168-169.)
201	29556	Germany ...	*Retractable Cooler Installed in Nose Wing Slot* (689,840). (Siebel (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 105.)
202	29557	Germany ...	*Fuel Drain for Sub-Divided Fuel Tanks, Operating Under all Conditions of Bank* (689,841). (Heinkel (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 105.)

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203	29558	Germany ...	*Immersed Fuel Pump Installations* (689,842). (Heinkel (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, pp. 105-106.)
204	29563	Germany ...	*Cable Arrester Gear for Aircraft* (687,927). (Arado (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 108.)
205	29567	Germany ...	*Anti-Dazzle Devices for Cockpits* (691,758). (Heinkel (Pat. Coll., No. 28), Flugsport, Vol. 32, No. 14, 3/7/40, p. 109.)
206	29568	Germany ...	*Device for Jettisoning Cockpit Roof* (691,836). (Henschel (Pat. Coll., No. 28), Flugsport, Vol. 32, No. 14, 3/7/40, pp. 109-110.)
207	29569	Germany ...	*Rotatable Jig for the Construction of Flat Aircraft Parts* (691,513). (Dornier (Pat. Coll., No. 28), Flugsport, Vol. 32, No. 14, 3/7/40, p. 111.)
208	29579	Germany ...	*Mass Balance of Ailerons and Flaps* (691,395). (Heinkel (Pat. Coll., No. 28), Flugsport, Vol. 32, No. 14, 3/7/40, p. 112.)
209	29571	Germany ...	*ITS—8M Motor Sailplane.* (Flugsport, Vol. 32, No. 15, 17/7/40, pp. 219-221.)
210	29572	Germany ...	*Amphibian Flying Boat H.122.* (Flugsport, Vol. 32, No. 15, 17/7/40, p. 221.)
211	29573	Germany ...	*Amphibian Flying Yacht Ha 23.* (Flugsport, Vol. 32, No. 15, 17/7/40, p. 222.)
212	29575	Germany ...	*Method of Changing Gear Ratio Between Main Rudder and Tab* (691,115). (Heinkel (Pat. Coll., No. 29), Flugsport, Vol. 32, No. 15, 17/7/40, p. 225.)
213	29576	Germany ...	*Steerable Tail Wheel* (690,056). (Arado (Pat. Coll., No. 29), Flugsport, Vol. 32, No. 15, 17/7/40, pp. 114-115.)
214	29577	Germany ...	*Wing Tip Floats* (690,819). (Dornier (Pat. Coll., No. 29), Flugsport, Vol. 32, No. 15, 17/7/40, p. 116.)
215	29580	Germany ...	*Variable Pitch Control Mechanism.* (Escher-Wyss (Pat. Coll., No. 34), Vol. 32, No. 20, 25/9/40, pp. 134-135.)
216	29583	Germany ...	*Pressure Surges in High Pressure Hydraulic Pipe Lines.* (G. Reid, Z.V.D.I., Vol. 85, No. 29, 19/7/41, pp. 639-643.)
217	29594	Germany ...	*Performance of Aircraft Wheels and Brakes.* (H. Burkhardt, Luftwissen, Vol. 8, No. 9, Sept., 1941, pp. 289-291.) (Abstract available.)
218	29601	Great Britain	*Reinforced Wood as an Airscrew Blade Material.* (W. R. Chown, Flight, Vol. 40, No. 1,717, 20/11/41, pp. 365-367.)
219	29603	Great Britain	*Calculation of the Stresses in Annular Frames.* (*R.T.P. Translation No.* 1,218.) (H. Fahlbusch and W. Weyner, J. Roy. Aeron. Soc., Vol. 45, No. 371, Nov., 1941, pp. 349-360.)
220	29613	Great Britain	*Pressure Cabins and Temperatures.* (H. M. T. Kittelsen, Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 303-305.)

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221	29617	U.S.A. ...	*Vibration Tests and Flutter (from the U.S.A.).* (C. B. Lyman, Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 311-317.)
222	29621	Germany ...	*Glass-Iron Concrete Combination for Skylight and Windows of Airport Structures.* (O. Volckers, Flughafen, Vol. 9, No. 8, Aug., 1941, pp. 9/13.)
223	29628	Germany ...	*High Speed Wing Profile (Pointed Nose and Suction Control Trailing Edge* (710,780). (D.V.L. (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 57.)
224	29629	Germany ...	*Adjustable Incidence for Wing Elevator Combination (Maintaining Altitude at Low Speeds)* (711,216). (Rohrbach (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 58.)
225	29630	Germany ...	*Method for Increasing Longitudinal Stability of Aircraft with Free Controls* (711,264). (Dornier (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, pp. 59-60.)
226	29631	Germany ...	*Aircraft Wheels* (711,859). (V.D.M. (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 61.)
227	29632	Germany ...	*Hot Air Control for Wing De-Icing* (709,354). (Focke-Wulf (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 63.)
228	29633	Germany ...	*Device for Protecting the Aircraft Wing Structure Against Damage from Air Escaping at High Pressure in Case Wheel Tyre is Punctured whilst in the Retracted Position (Automatic Deflation and Re-inflation)* (710,738). (Blackmann (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, pp. 61-62.)
229	29634	Germany ...	*Air Brake Control* (708,964). (Dornier (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 63.)
230	29635	Germany ...	*Brake Shoes for Aircraft Wheels* (712,010). (V.D.M. (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 62.)
231	29636	Germany ...	*Balanced Air Brakes of the Flap Type* (708,447). (D.F.S. (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, pp. 62-63.)
232	29637	Germany ...	*Hot Air Control for Wing De-Icing* (711,287). (Junkers (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, pp. 63-64.)
233	29638	Germany ...	*Variable Pitch Propeller Mechanism* (710,739). (Argus (Pat. Coll., No. 15), Flugsport, Vol. 33, No. 22, 29/10/41, p. 64.)
235	29653	Germany ...	*Fifteen Years' Operation by the Lufthansa—A Review of Some Outstanding Achievements Over this Period.* (T. Matthias, Flughafen, Vol. 9, No. 7, July, 1941, pp. 14-17.)
239	29684	Germany ...	*Bending Vibration of Airscrew Blades.* (E. Maier, Ing. Arch., Vol. 11, No. 2, April, 1940, pp. 73-98.)

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240	29685	Germany ...	*The Calculation of the Accelerated Longitudinal Motion of an Aircraft.* (W. Muller, Ing. Arch., Vol. 11, No. 2, April, 1940, pp. 99-117.)
			ENGINES AND ACCESSORIES.
241	29218	U.S.A. ...	*A History of Engine Supercharging.* (R. R. Dexter, J. Aer. Sci. (Rev. Sec.), Vol. 8, No. 11, Sept., 1941, pp. 41-43.)
243	29256	U.S.A. ...	*Problems of Engines Enclosed in Wings.* (G. W. Tweeney, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 142-144 and 224.)
244	29268	U.S.A. ...	*New Marvel Carburettor with Accelerating Pump.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 199.)
245	29287	Great Britain	*Turbo-Superchargers for Aeroplanes (I).* (S. A. Mass, Aeroplane, Vol. 61, No. 1,588, 31/10/41, pp. 492-494.)
246	29298	Germany ...	*The Machining of Aero Engine Fins with the Fay Automatic.* (E. Grund, Progressus, Vol. 6, No. 6, June, 1941, pp. 298-299.)
247	29299	Germany ...	*M.A.N. Transport Diesel with Specially Low Fuel Consumption (160 g./b.h.p. hour).* (Progressus, Vol. 6, No. 6, June, 1941, pp. 299-300.)
248	29308	Germany ...	*Guiberson Four-Stroke Diesel Aero Engine (320 h.p.).* (Flugsport, Vol. 32, No. 18, 28/8/40, pp. 275-277.)
249	29314	Germany ...	*Jet Propulsion (Patent No. 692,163).* (Patent Collection, Collection, No. 32, Stipa, Flugsport, Vol. 32, No. 18, 28/8/40, p. 128.)
250	29317	U.S.A. ...	*Fuel Injection for Aircraft Engines.* (P. M. Heldt, Autom. Ind., Vol. 85, No. 6, 15/9/41, pp. 18-21.)
251	29318	U.S.A. ...	*Pokormey Compression Ignition Engine Using Fuel/Air Mixture Injection.* (Autom. Ind., Vol. 85, No. 6, 15/9/41, p. 21.)
252	29326	Germany ...	*Isotta Fraschini Delta R.C. 35 and Gamma R.C. 35 (Air-cooled V).* (Flugsport, Vol. 32, No. 16, 31/7/40, pp. 236-237.)
253	29339	U.S.A. ...	*Wear and Scuffing of Cylinder Bore Irons.* (Metal Progress, Vol. 40, No. 3, Sept., 1941, pp. 322-323.)
254	29356	U.S.A. ...	*American Aircraft Engines (Alphabetical Digest).* (Aero Digest, Vol. 38, No. 3, March, 1941, pp. 202-224.)
255	29360	U.S.A. ...	*Allison V1710 E4 Engine with Extension Shaft.* (Aero Digest, Vol. 38, No. 3, March, 1941, p. 248.)
256	29384	U.S.A. ...	*Aircraft Power Plants Cooling Test.* (Civil Aircraft Regulations, U.S.A.)
257	29426	U.S.A. ...	*New U Type Four-Cylinder Light Plane Engine (Kettering) (Photograph).* (Autom. Ind., Vol. 85, No. 7, 1/10/41, p. 150.)
258	29430	U.S.A. ...	*Liquid v. Air-Cooled Engines (the Need for Both Types).* G. H. Brett, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 46-47.)

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259	29446	Great Britain	*Cast Engine Parts* (*Ford Motor Co. Technique*). (Autom. Eng., Vol. 31, No. 416, 6/11/41, pp. 379-382.)
260	29453	U.S.A. ...	*Electric Slip Couplings for Use with Diesel Engines for Ship Propulsion* (*with Discussion*). (A. D. Andriold, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 567-576.)
263	29465	Great Britain	*Discussion on Torque Reaction and Contra Props.* (Flight, Vol. 40, No. 1,715, 6/11/41, pp. 327-328.)
264	29472	Great Britain	*Turbo Superchargers for Aeroplanes—II.* (Aeroplane, Vol. 61, No. 1,589, 7/11/41, pp. 520-522.)
265	29473	Germany ...	*The Permissible Stressing of Gears and its Calculation in Machine Tool Construction.* (H. Hofer, Friedrichshafen Gear Wheel Company, Werkslattstechnik, Vol. 25, No. 5, 1/3/41, pp. 128-131.)
266	29486	Italy	*Fiat A82 R.C. 42S Radial Engines.* (Flugsport, Vol. 33, No. 16, 6/8/41, pp. 319-320.)
267	29516	Great Britain	1,500 *h.p. Ford V-12 Aero Engine.* (H. W. Perry, Flight, Vol. 40, No. 1,716, 13/11/41, pp. g-h.)
269	29526	Germany ...	*The Early History of the Junkers Opposed Piston Engine.* (Junkers Journal, Vol. 12, No. 1-2, Jan.-Feb., 1941, pp. 21-30.)
270	29528	U.S.A. ...	*Mercedes Benz D.B. 601A Aircraft Engine.* (R. W. Young, S.A.E.J., Vol. 49, No. 4, Oct., 1941, pp. 409-431.)
271	29546	Great Britain	*Fuel Injection in Oil Engines in Relation to Combustion* (*Discussion of Original Paper published in Proceedings, Vol. 144, p. 2*). (G. W. A. Green, Procs. Inst. Mech. Eng., Vol. 145, No. 3, June, 1941, pp. 137-141.)
272	29547	Italy	*Italian Four-Cylinder Light Plane Engine CNAD.* (Flugsport, Vol. 32, No. 11, 22/5/40, pp. 153-154.)
273	29555	Germany ...	*Measurement of Engine Power in Flight by Torque Reaction* (680,305). (Blohn and Voss (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 105.)
274	29560	Germany ...	*Engine Throttle Control Utilising a Compressed Gas/Liquid Mixture* (690,426). (Junkers (Pat. Coll., No. 27), Flugsport, Vol. 32, No. 12, 5/6/40, p. 106.)
275	29566	Germany ...	*Series Production of B.M.W. 132* (*Photograph*). (Flugsport, Vol. 32, No. 14, 3/7/40, p. 204.)
276	29578	Germany ...	*Two-Stroke Light Aircraft Engine 24 h.p., 300 cc.*). (Flugsport, Vol. 32, No. 20, 25/9/40, pp. 314-315.)
277	29582	Germany ...	*Cast Iron as Material for Journal Bearings.* (W. Meboldt, Z.V.D.I., Vol. 85, No. 29, 19/7/41, pp. 637-638.)
278	29584	Germany ...	*Review of Recent Researches on Two-Stroke Transport Engines.* (Z.V.D.I., Vol. 85, No. 29, 19/7/41, pp. 643-645.)
279	29588	Germany ...	*Materials for Cylinder Liners.* (C. Englisch, A.T.Z., Vol. 44, No. 12, 25/6/41, pp. 305-312.)
280	29612	Germany ...	*Mercedes Benz D.B. 601A Engine* (*an American Examination*). (R. W. Young, Airc. Eng., Vol. 13, No. 153, Nov., 1941, pp. 300-302 and 305.)

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281	29626	Germany ...	*Possibilities of Jet Propulsion.* (Flugsport, Vol. 33, 29/10/41, p. 439.)
282	29658	U.S.A.	*Aircraft Engine Superchargers.* (H. L. Brownback, Autom. Ind., Vol. 85, No. 8, 15/10/41 pp. 22-25 and 31.)
283	29659	U.S.A. ...	*Bending Moment in the Master Rods of Radial Aircraft Engines.* (L. M. Porter, Autom. Ind., Vol. 85, No. 8, 15/10/41, pp. 26-31.)
284	29660	U.S.A. ...	*Manufacture of Borg and Beck Fluid Coupling.* (Autom. Ind., Vol. 85, No. 8, 15/10/41, pp. 37-39.)
285	29668	Germany ...	*Effect of Type of Dust on Experimental Results with Engine Dust Filters.* (Z.V.D.I., Vol. 85, No. 39-40, 4/10/41, p. 800.)
286	29679	U.S.A. ...	*Induction Hardening of Crankshafts Yields Better Products.* (Sci. Amer., Vol. 165, No. 5, Nov., 1941, pp. 255-256.)
287	29688	Germany ...	*The Effective Torsional Rigidity in the Torsional Vibrations of Crankshafts (Dynamic Flexibility).* (R. Grammel, Ing. Arch., Vol. 11, No. 2, April, 1940, pp. 149-150.)
288	29690	Germany ...	*The Graphical Determination of the Natural Frequencies of Various Systems (Crankshaft Torsionals and Bending Vibration of Beams).* (O. Foppl, Ing. Arch., Vol. 11, No. 3, June, 1940, pp. 178-191.)
289	29695	Germany ...	*Review of British and American Researches on Cylinder Wear.* (A.T.Z., Vol. 44, No. 13, 10/7/41, pp. 335-341.)
290	29696	Germany ...	*Gear Design for Transport Vehicles.* B. Eckert, A.T.Z., Vol. 44, No. 13, 10/7/41, pp. 342-345.)
291	29697	Germany ...	*Engine Stresses Due to Rapid Rise of Combustion Pressure or Knock.* (T. Geiger, A.T.Z., Vol. 44, No. 13, 10/7/41, pp. 327-335.) (Abstract available.)
			INSTRUMENTS.
292	29245	U.S.A. ...	*Controlled Approach Lighting (Airport Instrument Landing System).* (D. S. Little, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 72-79, 228-230.)
293	29265	U.S.A. ...	*Kollsman Direction Indicator Compass with Inclined Dial.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 196.)
294	29267	U.S.A. ...	*Time and Distance Computor.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 198.) (Abstract available.)
295	29316	U.S.A. ...	*Improvements in Rizo Electric Indicators (from the German).* (Autom. Ind., Vol. 85, No. 6, 15/9/41, p. 17.)
296	29334	Germany ...	*Equalisation of Torsion in the Flexible Shaft Control of Distant Reading Compass (Patent No. 692,873).* (Patent Collection, No. 39, Siemens, Flugsport, Vol. 32, No. 16, 31/7/40, p. 120.)

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297	29359	U.S.A. ...	*Pre-Computed Altitude in Celestial Navigation.* (W. C. Youngclaus, Aero Digest, Vol. 38, No. 3, March, 1941, pp. 246 and 252.)
298	29395	Great Britain	*The Compass and Other Aids to Navigation.* (F. C. Stewart, The Engineer, Vol. 172, No. 4,477, 31/10/41, pp. 298-300.)
299	29432	U.S.A. ...	*Navigation with the Direction Finding Loop.* (C. H. Mackintosh, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 52-53 and 158-162.)
300	29434	U.S.A. ...	*Instrument Equipment for Flight Testing of Aircraft Engines.* (H. Shebat, Aviation, Vol. 40, No. 9, Sept., 1941, pp. 69 and 176-180.)
301	29440	U.S.A. ...	*New Link Bubble Octant and Collimator.* (Aviation, Vol. 40, No. 9, Sept., 1941, pp. 82-84.)
302	29512	U.S.A. ...	*"Vibrometer" Vibration Indicator (Tuned Reed).* (Ind. and Eng. Chem. (News Ed.), Vol. 19, No. 19, 10/10/41, p. 1,102.)
			FUELS AND LUBRICANTS.
303	29235	U.S.A. ...	*Sludge Formation in Distillate Fuel Oils.* (R. J. Hawes and F. M. Miller, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 10, Oct., 1941, pp. 1,318-1,320.)
304	29236	U.S.A. ...	*Mineral Oil Deterioration.* (J. C. Balsbaugh and others, Ind. and Eng. Chem. (Ind. Ed.), Vol. 33, No. 10, Oct., 1941, pp. 1,321-1,330.)
305	29319	U.S.A. ...	*Gas Generator Plants on French Transport Vehicles.* (Autom. Ind., Vol. 85, No. 6, 15/9/41, pp. 32-33.)
306	29404	Great Britain	*Quarterly Bibliography of Lubrication, No. 35, July-Sept.*, 1941. (Sci. Lib. Bibliog. Series.)
307	29455	U.S.A. ...	*Combustion Explosions in Pressure Vessels Protected with Rupture Disks.* (M. D. Creech, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 583-588.) (Abstract available.)
308	29408	U.S.A. ...	*Flow Properties of Lubricants Under High Pressure (with Discussion).* (A. E. Norton and others, Trans. A.S.M.E., Vol. 63, No. 7, Oct., 1941, pp. 631-643.) (Abstract available.)
309	29529	U.S.A. ...	*Engineering for Better Fuel Economy (Motor Cars).* (H. T. Youngren, S.A.E.J., Vol. 49, No. 4, Oct., 1941, pp. 432-441.)
310	29532	U.S.A. ...	*Evaluation of Diesel Fuels in Full-Scale Engines.* (W. G. Ainsley, S.A.E.J., Vol. 49, No. 4, Oct., 1941, pp. 448-460.)
311	29533	U.S.A. ...	*Lubrication of Severe-Duty Engines (Diesels). (Discussion on paper published in S.A.E. Journal, Aug., 1941, pp. 309-325.)* (J. G. McNab and others, S.A.E.J., Vol. 49, No. 4, Oct., 1941, pp. 461-464.)
312	29540	U.S.A. ...	*Liquefied Gas Storage Tanks.* (The Welding Engineer, Vol. 26, No. 7, July, 1941, pp. 25-26.)

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313	29589	Germany ...	*Novel Types of Gas Generators for Transport Vehicles.* (A.T.Z., Vol. 44, No. 12, 25/6/41, p. 318.)
314	29642	Germany ...	*Regeneration of Used Lubricating Oil.* (H. Foulson, Flughafen, Vol. 9, No. 6, June, 1941, pp. 5-7.)
315	29652	Great Britain	*Colloidal Fuel (from the U.S.A.).* (J. E. Hedrick, Engineer, Vol. 172, No. 4,480, 21/11/41, pp. 361-362.)

MATERIALS.

316	29221	Great Britain	*Synthetic Adhesives for Plywood Manufacture.* (Engineer, Vol. 172, No. 4,476, 24/10/41, p. 282.)
317	29234	Great Britain	*Axially Symmetrical Stress in a Thick Tube.* (A. M. Binnie, Phil. Mag., Vol. 32, No. 213, Oct., 1941, pp. 336-347.)
318	29238	Great Britain	*Buckling of Plates with Lateral Stiffeners.* (H. Yushan, J. Roy. Aeron. Soc., Vol. 45, No. 370, Oct., 1941, pp. 326-330.)
319	29259	U.S.A. ...	*Sheet Metal Drafting, Part I (Surface Geometry).* (C. Belsky, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 152-160 and 223.)
320	29260	U.S.A. ...	*Heat Treating of Aircraft Materials.* (N. E. Woldman and C. H. Fetzer, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 163-168, 223-224.)
321	29262	U.S.A. ...	*New "Roxalin" Fabric Finish for Aircraft Speed Production.* (W. F. Smith and A. B. Marsh, Aero Digest, Vol. 39, No. 2, Aug., 1941, pp. 175-176, 224-227.)
322	29269	U.S.A. ...	*Flexible Air Hose for Pneumatic Tools.* (Aero Digest, Vol. 39, No. 2, Aug., 1941, p. 200.)
323	29270	U.S.A. ...	*Bessemer Steel Process Re-introduced in the U.S.A.* (Sci. Am., Vol. 165, No. 4, Oct, 1941, p. 193.)
324	29275	U.S.A. ...	*Designing for Machinability (II).* (J. E. Thompson, Aero Digest, Vol. 38, No. 4, April, 1941, pp. 114-118.)
325	29276	U.S.A. ...	*High Speed Production Spot Welding of Al. Alloy.* (Aero Digest, Vol. 38, No. 4, April, 1941, pp. 121-122.)
326	29277	U.S.A. ...	*Superfinish—Its Aircraft Application.* (M. W. Petrie, Aero Digest, Vol. 38, No. 4, April, 1941, pp. 125-130.)
327	29288	Great Britain	*A New Chromising Process (Diffusion).* (D. W. Rudorff, Metal Industry, Vol. 59, No. 13, 26/9/41, pp. 194-195.)
328	29289	Great Britain	*Deep Drawing and Pressing of Al. and Light Alloy Sheet, II.* (J. D. Jevons, Metal Industry, Vol. 59, No. 13, 26/9/41, pp. 197-199.)
329	29290	Great Britain	*Spot Welding of Al. Alloy for Aircraft by Three-Phase Short Wave Process.* (Metal Industry, Vol. 59, No. 13, 26/9/41, p. 203.)
330	29291	Great Britain	*G.E.C. Heavy Alloy (Tungsten-Nickel-Copper).* (Nature, Vol. 148, No. 3,756, 25/10/41, p. 507.)

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331	29296	Germany ...	*Machine Tools for Fine Parts.* (K. Rabe, Progressus, Vol. 6, No. 6, June, 1941, pp. 265-277.)
332	29297	Germany ...	*The Employment of Light Alloy in Transport Vehicles (Design and Constructional Features).* (W. Bleicher, Progressus, Vol. 6, No. 6, June, 1941, pp. 284-291.)
333	29335	Great Britain	*The Mechanical Properties of Solids.* (E. N. da C. Andrade, Nature, Vol. 148, No. 3,757, 1/11/41, pp. 520-525.)
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349	29401	Great Britain	*Precautions in Using Radium Paint.* (Engineering, Vol. 152, No. 3,955, 31/10/41, p. 360.)
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Longitudinal Stability and Airscrew Rotation (*Inter. Avia.*, No. 759, 9/4/41), *J.*, XLV., p. 138.

Longitudinal Dynamic Stability of an Aeroplane with an Automatic Pilot (*Aeron. Eng., U.S.S.R.*, Jan., 1941), *J.*, XLV., p. 105.

STABILITY—SPINNING

Spin Tests of a Low Wing Monoplane in Flight and in the Free Spinning Wind Tunnel (*N.A.C.A. Tech. Note* No. 769, July, 1940), *J.*, XLV., p. 25.

The Aileron as an Aid to Recovery from the Spin (*N.A.C.A. Tech. Note* No. 776, Sept., 1940), *J.*, XLV., p. 27.

Free-Spinning Wind Tunnel Tests of a Low Wing Monoplane with Systematic Changes in Wings and Tails v. Effect of Aeroplane Relative Density (*N.A.C.A. Report* No. 691, 1940), *J.*, XLV., p. 7.

STEEL, *see* Materials—Steel.

STRATOSPHERE

The Chemical Exploration of the Stratosphere (*Chemistry and Industry*, 4/1/41), *J.*, XLV., p. 58.

STRESSED SKIN, *see* Materials—Stressed Skin.

STRUCTURES—THEORY OF, *see* Materials—Theory of Structures.

SUPERCHARGING, *see* Engines—Supercharging.

SUPERSONIC SPEEDS, *see* Aerodynamics—Supersonic.

TESTING, *see* Engines—Testing; Materials—Testing.

THEORY OF STRUCTURES, *see* Materials—Strength of; Materials—Stressed Skin; Materials—Theory of Structures.

TRANSLATIONS

J., XLV., pp. 19, 39, 60, 87, 151, 186, 242, 288, 351, 405.

TUBES, *see* Materials—Tubes.

TURBINES, *see* Engines—Turbines.

TURBULENCE, *see* Aerodynamics—Turbulence.

UNDERCARRIAGES, *see* Aeroplanes—Undercarriages.

VALVES, *see* Engines—Valves.

VIBRATION

The Effect of Foundation Stiffness on the Resonant Frequencies of Rotating Machines (*J. App. Mech.*, Sept., 1941, U.S.A.), *J.*, XLV., p. 399.

Damping of Torsional Vibrations by Means of Electrically Coupled Masses with Non-Linear Spring Constants (*L.F.F.*, 28/2/41, Germany), *J.*, XLV., p. 111.

Some Experiments on the Forced Vibration of Varying Period (*Aer. Res. Inst., Tokyo*, Report No. 195, Aug., 1940), *J.*, XLV., p. 35.

The Vibration Damping Capacity of Mn-Cu Alloys (*Trans. Am. Soc. Metals*, June, 1941), *J.*, XLV., p. 446.

VISIBILITY, *see* Optics.

WARFARE—AERIAL

Aircraft versus Submarine (*Aeroplane, U.S.S.R.*, May, 1941), *J.*, XLV., p. 269.

New Air Force Tactics in the Present War (*Aeroplane, U.S.S.R.*, Jan., 1941), *J.*, XLV., p. 267.

Echo Sounder for Air Defence (*Inter. Avia.*, No. 764-765, 19/5/41), *J.*, XLV., p. 268.

The Rôle of the Air Force in the Battle of the Ionian Islands (27-29 March) (*La Science et la Vie*, June, 1941, France), *J.*, XLV., p. 221.

The Use of Dummies in the Camouflage of Operational Aerodromes (*Air Fleet News, U.S.S.R.*, Vol. 23, No. 5), *J.*, XLV., p. 221.

WARFARE—AERIAL—A.R.P.

Canopy Unit for Protecting Vital Plant during Raids (*Engineer*, 25/4/41), *J.*, XLV., p. 135.

German Shelter Buildings (*Inter. Avia.*, No. 676, 7/6/41), *J.*, XLV., p. 323.

Aerial Barrages (Barrage Balloons, Aerial Mines and Kites) (L. Schuttel, published by Lehmann, 1939, Germany), *J.*, XLV., p. 323.

Influence of War Experiences on the Development of A.R.P. Lighting (*E.T.Z.*, 13/6/40), *J.*, XLV., p. 183.

German Air Raid Defence of Factories (*Chem. and Metallurgical Engineering*, April, 1941, U.S.A.), *J.*, XLV., p. 218.

WEIGHT (AIRCRAFT), *see* Aeroplanes—Design and Construction.

WELDING, *see* Materials—Welding.

WINDSHIELD WIPERS, *see* Aeroplanes.

WIND TUNNELS

The Resistance Coefficient of Commercial Types of Wire Grids (*L.F.F.*, 22/4/41, Germany), *J.*, XLV., p. 185.

Contribution to the Theory of Wind Tunnel Turbulence (*Z.A.M.M.*, Feb., 1941, Germany), *J.*, XLV., p. 270.

U.S. Army Air Corps New Wind Tunnel (*Inter. Avia.*, No. 772/773, 15/7/41), *J.*, XLV., p. 330.

M.I.T. Wright Brothers Wind Tunnel and its Operating Equipment (*J.S.A.E.*, Sept., 1941, U.S.A.), *J.*, XLV., p. 387.

A New Wind Tunnel Balance for Model Airscrew Experiments (*Atti di Guidonia*, No. 44, 20/2/41, Italy), *J.*, XLV., p. 275.

Wind Tunnel Correction for a Circular Open Jet Tunnel with a Reflection Plate (*Proc. Roy. Soc.*, 24/2/41), *J.*, XLV., p. 73.

Cascade Theory and the Design of Fan Straighteners (*A.R.C.* R. & M. No. 1885), *J.*, XLV., p. 74.

The Effect of Nozzle and Collector on Resistance Measurement in the Free Jet Wind Tunnel (*Z.A.M.M.*, Feb., 1941, Germany), *J.*, XLV., p. 270.

WIRELESS

Oblique Incidence Radio Transmission and the Lorentz Polarization Term (*Bur. Stan. J. Res.*, Feb., 1941, U.S.A.), *J.*, XLV., p. 401.

Diffraction Theory of Electromagnetic Waves (*Physical Review*, July, 1939, U.S.A.), *J.*, XLV., p. 401.

An Omni-Directional Radio Range System (*R.C.A. Review*, July, 1941, U.S.A.), *J.*, XLV., p. 346.

On Starting an Electric Spark by intense Ionisation of the Sparking Space (*Inst. of Phys. and Chem. Res., Tokyo*, Scientific Paper No. 1022), *J.*, XLV., p. 346.

Determination of the Average Life of Vacuum Tubes (*Bell Laboratories Record*, Aug., 1940, U.S.A.), *J.*, XLV., p. 150.

The Effect of Rain and Fog on the Propagation of very Short Radio Waves (*Proc. I.R.E.*, June, 1930, U.S.A.), *J.*, XLV., p. 347.

Theory of the Electro-Magnetic Horn (*Proc. I.R.E.*, Jan., 1939, U.S.A.), *J.*, XLV., p. 349.

Electro-Magnetic Horn Design (*A.I.E.E. Trans.*, July, 1939, U.S.A.), *J.*, XLV., p. 348.

Aircraft Radio, 1939 (*Electronics*, Jan., 1939, U.S.A.), *J.*, XLV., p. 348.

Theoretical and Experimental Investigations of Electron Motions in Alternating Fields with the Aid of Ballistic Models (*Proc. of I.R.E.*, Feb., 1941, U.S.A.), *J.*, XLV., p. 347.

Acoustic Models of Radio Antennas (*Procs. of I.R.E.*, April, 1941, U.S.A.), *J.*, XLV., p. 283.

Ultra Short Wave Transmission over a 39-mile "Optical" Path (*Proc. Inst. Rad. Engs.*, Aug., 1940), *J.*, XLV., p. 17.

WIRELESS—DIRECTION FINDING

A Mechanical Calculator for Directional Antenna Patterns (Digest) (*Procs. of I.R.E.*, April, 1941, U.S.A.), *J.*, XLV., p. 284.

The CAA-MIT Microwave Instrument Landing System (*A.I.E.E. Trans.*, 1940, pp. 859-864, U.S.A.), *J.*, XLV., p. 347.

Devices for Locating Airliners on their respective Courses (*Inter. Avia.*, No. 753, 6/3/41), *J.*, XLV., p. 182.

X-RAYS

X-Ray Analysis in Industry (*J. Sc. Inst.*, July, 1941), *J.*, XLV., p. 345.

X-Ray Analysis in Industry (*J. Sci. I.*, May, 1941), *J.*, XLV., p. 181.

A new use for X-Rays in Industry (*Electronics*, April, 1941), *J.*, XLV., p. 180.

Evidence on the State of Fatigue of Metals obtained by determination of Surface Stresses by means of X-Rays (*Z.V.D.I.*, 4/10/41, Germany), *J.*, XLV., p. 450.

X-Ray Examination of Mg Alloy Castings (*Luftwissen*, Sept., 1941, Germany), *J.*, XLV., p. 450.

Printed in Great Britain by the Lewes Press (Wightman & Co., Ltd.), Lewes

A

LIST

of the

Books, Periodicals and Pamphlets

in the

LIBRARY

of

The Royal Aeronautical Society

With which is incorporated The Institution of Aeronautical Engineers

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London:
4, Hamilton Place, Hyde Park Corner, W.1.
1941.

INTRODUCTORY NOTE.

The Library of the Royal Aeronautical Society started from very small beginnings, though its foundations were almost simultaneous with the foundation of the Society in 1866. That fact is revealed in the Society's first Annual Report, published early in the year following, which contains an acknowledgment of books and pamphlets presented by members and others, a practice which was continued in future Reports up to the time they were discontinued in 1893. Though these gifts came mostly from members, it is of interest to note that they came also from pioneers of flight in France, Germany, Italy, Russia and the United States. For instance, Alphonse Pénaud, one of the most notable pioneers of his time in the field of aeronautics, presented in 1870 a copy of his "Appareils de Vol Mécanique," while Otto Lilienthal, more widely known for his experiments with gliding machines, presented in 1890 his book on "Der Vogelflug als Grundlage der Fliegkunst." Indeed, the widespread origin of these presentation copies, coupled with the fact that such distinguished foreigners as Pénaud, Lilienthal and others were elected members, gave to the Society in its earlier years something of an international character.

During the last ten years or so of the nineteenth century, however, the Library must have suffered neglect, and acquisitions by way of gift must have almost ceased. Membership at this time had dwindled to a very small number, and the Honorary Secretary, F. W. Brearey, though faithful to the last in the cause he had supported with vigour and enthusiasm during his long life—he died at the age of 88—was one of the few surviving original members. Under these discouraging circumstances the small collection of books that had been formed became in part dispersed, with the result that some interesting presentation volumes were regrettably, though perhaps inevitably, lost to the Society. But when, within a few years of the resuscitation of the Society in 1897, there was a renewal of the endeavour to build up a Library, it again became the practice to acknowledge in the pages of the "Aeronautical Journal" from 1904 onwards, the gift of books and pamphlets. In later years the acquisitions have been supplemented by free review copies submitted by publishers—as to which a few words are added at the end of this Note.

Turning to the Library as it exists to-day, it may be said, broadly speaking, to consist of two sections, the one comprising books of historical interest, and the other modern scientific and technical works. To these must be added the extensive collection of pamphlets, some of which are of a historical character, but the majority scientific.

The Historical section comprises a representative collection of English and foreign books—many of great rarity—dealing with aeronautical ideas and endeavours from the 17th to the 19th century. Though there are many lacunæ —the literature of the subject is far wider than is generally realised—the Library does contain most of the books in this category. Of the more valuable books the greater number were purchased in 1922 owing to a grant of £500 made for the purpose by the Carnegie United Kingdom Trustees.

In connection with the Historical section mention should be made of treasures other than books—such, for instance, as the original specification, with scale drawings, of W. S. Henson's "Ariel Steam-Carriage," 1843—the first complete design for a power-driven monoplane. Only one other copy—that in the Patent Office—of this interesting specification is known to be extant, and it is an important addition, made by purchase in 1935, to the long file of Aeronautical Patents presented to the Society for many years past by the Commissioners for Patents. Other items of interest include the extensive collection of news cuttings and illustrations, in a series of large albums, formed by the late Major B. Baden-Powell, and the even more valuable collection of scarce prints and other material relating to the many aspects of flight, gathered and bound in 12 folio volumes by Dr. F. J. Poynton and by him generously presented to the Society.

The Scientific section of the Library, much larger and more comprehensive than the Historical, comprises a thoroughly representative collection of the best books on modern aeronautical science and technology. It may, in short, be said that the research worker, the designer and the student alike will find in this section most, if not all of the latest books essential to their studies, ranging from the most learned treatises and papers to quite elementary handbooks and text-books. In addition to the separate works, this section also comprises the more important English and foreign periodicals, as well as the numerous annual and other Reports issued officially by the Governments and scientific institutions of various countries.

As to the extensive collection of Pamphlets, it need only be said that these have recently been classified and catalogued for the first time, and they are all included in the Subject Index of the present catalogue.

Though not, strictly speaking, forming part of the Library, mention may also be made of the collections of Autographs, and likewise of Lantern Slides and Photographs. In the former, the most important feature is the letter-books of Lawrence Hargrave, containing a mass of material—which has never been studied as carefully as its interest and importance deserves—relating to the work of this eminent British pioneer of flight between about 1884 and 1909. These thick folio albums contain not only numerous letters which passed between Hargrave and his aeronautical contemporaries, but also many carefully executed drawings of the inventor's own gliders, kites and engines. The Society's archives also include many interesting letters on aeronautical matters written mostly by members over the first fifty years of its existence, as well as others from such famous pioneers as, for instance, the Wright brothers.

The Lantern Slides—of which there is a card index, and which are available to members for lecture purposes—together with the Photographs of all types of historical and modern flying machines and dirigible balloons, must form one of the most extensive and important collections of the kind in existence. Their great value as historical material will certainly increase as the years go by, and it is therefore fitting that full credit should be given to the present Secretary, Captain J. L. Pritchard, to whose foresight it is so largely due.

In conclusion, a few words as to the future of the Library, more particularly the matter of acquisition and upkeep. As previously mentioned, the growth of the Library has been greatly due in the past, as it continues to be in the present, to the generosity of members, which certainly deserves appreciation. But it is not desirable that the Society should depend wholly on benefactions. Still less is it befitting the dignity of the Society that it should be under the necessity, from time to time, of asking publishers to send in free copies of aeronautical books for review—a practice which must occasionally make it a little difficult to review such books with complete impartiality. Further, there are the important questions of the purchase of foreign books, of binding and repairing—the latter far too often neglected in Institution libraries.

Hitherto, save for occasional grants, there has been no special fund for the above purposes. I would therefore urge that as soon as circumstances permit, a Library fund should be formed for the purposes above mentioned. The long overdue appointment of a Librarian, Miss F. M. Buss, has already been fully justified in the revision of the classification, in the present catalogue, and in other ways that make for greater efficiency and more helpful service to readers. It only remains to afford the money necessary to maintain the Library in the high place it holds amongst special libraries as one of the finest aeronautical collections in the world. That fact, coupled incidentally with the beauty of the conditions in which the Library is housed, is one of which the Society at large is justly entitled to be proud. But it carries with it the obligation to see that its status is fully maintained.

J. E. Hodgson, *Hon. Fellow,*
Honorary Librarian.

LIBRARY CATALOGUE.

Classification.

Following the opening of the Society's new Headquarters at No. 4, Hamilton Place, London, W.1, the Library has been reorganised and catalogued. The system used is based primarily on the alphabetical plan given in the American Aeronautical Chamber of Commerce Yearbook for 1919, simplified and modified to suit the needs of the Society's library. This classification has the two great advantages of elasticity and precision. New sections can be added within the existing framework without disturbing the rest, and no account is taken of location, so that books can be shifted from one case to another as necessary.

Arrangement of Sections.

At the beginning of each section are placed official, collective or anonymous works which cannot be ascribed to any one author; the remaining books are arranged alphabetically under names of authors. Foreign books, grouped in their respective languages and also alphabetically under authors' names, are placed together at the end of the section.

Exceptions to this arrangement are: Biographies, alphabetical under name of subject; Conference and Congress Reports, in date order; Year-Books and Directories, alphabetical under title.

Special sub-divisions have been used in such cases as Civil Aviation, where official reports are classified under their country of origin, and Materials, where books dealing with one specific material (aluminium, rubber, timber, etc.) have been grouped together.

Card Index.

The card index is divided into three sections: Authors, Subjects and Titles (this last listing *books only*). It has cards of four colours: white for ordinary books, pink for books which are for reference only, blue for bound volumes of magazines, and yellow for pamphlet literature. One star before the reference number (*) indicates that the book may not be taken out on loan without special permission; two stars (**) are for books of special historical interest or intrinsic value, which are kept in a locked case apart from the general collection. In the case of foreign books, a capital letter in brackets follows the reference number, indicating the language; *e.g.*, D.b.30 (R/G) shows that the text of the book is interleaved Russian and German. (A guide card placed by the card-index boxes gives a list of the letters used.)

Box File and Pamphlet Literature.

This is classified in four main sections:—

a. Pamphlet Boxes.—These follow the headings of the Subject Index for books, but with the prefix "P,"

e.g., Section "A"=Dynamics.
Section "PA"=Pamphlets on Dynamics.

b. Bound Volumes of Pamphlets.—Indicated by the prefix " p " before the Section heading,

e.g., Section " B "≡Aircraft (Types).

Volumes pB.1, pB.2, etc.=bound pamphlets dealing with Aircraft Types.

c. Box File Literature.—This has the distinguishing prefix " Y," followed by the number of the file. (A list of these files is given in the Subject Index. There is no hard-and-fast distinction between the pamphlet box and box file literature; but in general the box files are used for paper works such as lecture proofs, reprints and stencils, while more compact booklets are in the pamphlet boxes. Box files are also used in cases where there is a quantity of pamphlet literature by one particular author or society (*e.g.*, Dr. F. W. Lanchester; the Smithsonian Institution; Air Ministry D.T.D. Specifications, etc.).

To obviate constant reshuffling, literature in both these classes is arranged in date order, the earliest at the bottom, except in cases such as Aircraft Types, Biographical Data, etc., where an alphabetical classification is obviously indicated. An index is placed at the beginning of each file.

d. Reports of Research Institutions.—Indicated by the prefix " U," followed by a letter showing the country of origin (UA=American, UB=British, etc.). Special sections are given to the Aeronautical Research Committee (AA) and the National Advisory Committee for Aeronautics (UU).

Such reports are indexed under their Authors in the card index, and collectively under the name of the issuing Society in Section III of the Catalogue.

Works under headings (*a*), (*b*) and (*c*) have a double reference number; *e.g.*:—

A.a.174	A.a.238	A.a.257
PA.2.a.9	Y.1.d.5	pA.3/7

The upper figure is a Subject reference, the lower a Location reference. In the cases cited above, all three pamphlets belong to Section A.a. (Aerodynamics); the first is the 9th pamphlet in division *a* of pamphlet box No. 2 in Section PA (Dynamics); the second is the 5th pamphlet in division *d* (Laboratories and Wind Tunnels) of box file 1 (Aerodynamics); the third is the 7th pamphlet in the third bound volume of pamphlets dealing with Aerodynamics.

Works under heading (*d*) merely have a reference to the issuing Society, unless they are collected in a box file; *e.g.*, UF.3 will be found, on reference to the Subject Index, to indicate the third series of French Reports (Ministère de l'Air, Publications Scientifiques et Techniques). No further reference is necessary, as these reports are issued with their own series number.

$\frac{\text{UH.4}}{\text{Y.28}}$ is a publication of the R. Politicnico di Torino (the fourth series of Italian reports listed), and is located in box file Y.28.

Shelf Indicators.

Each section is clearly marked on a slip of card fixed on the shelf below it. We hope that readers will make use of these guides in order to find the books they want.

LIBRARY CLASSIFICATION.

(* at the head of a Section indicates that all books in it are for reference only.)

A. DYNAMICS.
- a. Aerodynamics.
- b. Hydrodynamics.
- c. Thermodynamics.
- d. Wind-Tunnels and Laboratories.

AA. AERONAUTICAL RESEARCH COMMITTEE.

B. AIRCRAFT (TYPES).
- a. Aeroplanes.
- b. Rotorcraft.
- c. Gliding and Gliders, Soaring Flight, Ornithopters.
- d. Aircraft Carriers and Bases.
- e. Model Aircraft.
- f. Animal Flight.
- *g. Aircraft Recognition Books.

BB. AIRCRAFT (CONSTRUCTION).
- a. Text-Books.
- b. Design and Construction.
- c. Airscrews and Propellers.
- d. Aircraft Components and Accessories.
- e. Firms and Works.
- f. Aircraft and Scientific Instruments and Apparatus.

C. AEROSTATION.
- a. Theory of Aerostation; Gases.
- b. Kites.
- c. Free and Captive Balloons.
- d. Airships.
- e. Airship Accident Reports.
- f. Parachutes.

D. CIVIL AVIATION.
- a. Official Reports.
  - A. American
  - B. British.
  - C. British Empire.
  - D. French.
  - E. German.
  - F. Italian.
  - G. Russian.
  - H. Other Countries.
- b. Air Transport and Air Mail.
- c. Airports.
- d. Careers in Aviation.
- e. Economics of Air Transport.
- f. Safety, Accidents and Insurance.

E. ENGINEERING.
- a. Text-Books.
- b. Engineering Theory.
- c. Strength and Properties of Materials.
- d. Draughtsmanship and Workshop Practice.
- e. Engineering Economics.
- f. Ground Engineering.
- g. Hydraulics.

EE. ENGINES.
- a. Types (Official Hand-books).
- b. Types (General Information).
- c. Theory of Internal Combustion Engines.
- d. Carburettors and Carburation.

c. Magnetos, Ignition and Starting Devices
f. Gas and Oil Engines.
g. Steam Engines.
h. Compressed Air, Turbo-Blowers and Turbines
j. Engine Parts and Accessories.

F. FUELS.

a. Fuel Systems.
b. Fuels.
c. Lubricants.

G. MATERIALS.

a. Text-books and General Information.
b. Specifications.
c. Testing.
d. Special Processes.
e. Specific Materials.

A. Aluminium and its Alloys
B. Brass and Copper.
C. Nickel.
D. Plastics.
E. Steel and Iron.
F. Rubber.
G. Timber.
H. Tin.
J. Miscellaneous Metals and Minerals.
K. Fabrics, Dopes and Adhesives, Paints.

f. Welding.

H. LAW.

a. General.
b. Aviation Law.
c. Recognition Markings and Signals.

I. MATHEMATICS.

a. Text-books.
b. Calculus.
c. Higher Mathematics.
d. Elasticity.
*e. Tables.

J. METEOROLOGY.

a. Meteorological Office and Air Ministry Publications.
b. India Meteorological Department.
c. Overseas Meteorological Reports.
d. Smithsonian Institution Publications (bound volumes).
e. Royal Meteorological Society.
f. U.S. Weather Bureau.
g. General Works.

K. STRATOSPHERE.

a. Upper Air Conditions.
b. Stratosphere Exporation.
c. Astronavigation and Rocket Propulsion (Theory).

L. PRACTICAL AVIATION.

a. The Student Pilot (Flying Instruction).
b. The Sporting Pilot (Non-Technical Aeronautical Manuals)
c. The Commercial Pilot (Blind and Test Flying).
d. Navigation.
e. Form of the Earth, Maps and Charts (Theory).
f. Magnetism and Compasses.
g. Navigation Tables and Almanacs.
h. Aerial Guide-books and Maps.
j. Aerial Photography and Survey.
k. Aviation Medicine.

M. ELECTRICITY AND WIRELESS.

a. Electricity.
b. Wireless Telegraphy and Telephony (General).
c. Aeronautical Radio and Direction-Finding.
d. Projectors and Searchlights.

N. SCIENCE AND PHYSICS.

a. General Works.
b. Theory of Sound.
c. Chemistry.

*OO CONFERENCE AND CONGRESS REPORTS.

*P. PATENTS.

a. Specifications.
b. General Information.
c. Abridgments of Specifications.

Q. BIBLIOGRAPHY AND EDUCATION.

a. Bibliographies and Library Catalogues.
b. Library and Museum Information.
c. Colleges, Technical Training.
d. Miscellaneous Information.
e. Catalogues of Prints and Sketches

R. HISTORICAL.

a. 1500-1782.
b. 1783-1903.
c. 1904-1913.
d. 1914-1918. (For GREAT WAR see Section S.a.)
e. 1919-1929.
f. 1930 onwards.

RR. OBSOLETE TECHNICAL BOOKS.

S. MILITARY AVIATION. (Prior to 1914 see under HISTORICAL).

a. The Great War (1914-18).
b. Royal Air Force.
c. Foreign Air Forces.
d. Modern Air Warfare.
e. War with Germany, 1939.

T. LITERATURE OF FLIGHT.

a. Biographies and Biographical Data.
b. Memoirs and Famous Flights.
c. Arctic and Antarctic Exploration.

TT. FICTION AND ART.

a. Prose.
b. Verse.
c. Music, Sketches, Prints, Stamps, etc.

U. REPORTS OF RESEARCH INSTITUTIONS.

A. American.
B. British.
C. British Empire.
D. Czechoslovakian.
E. Dutch.
F. French (language).
G. German (language)
H. Italian.
J. Polish
K. Russian.
L. Asiatic Countries.

UU. NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS (U.S.A.).
- a. Technical Notes.
- b. Reports.
- *c. Technical Memoranda.
- *d. Translations of Technische Berichte.
- *e. Aircraft Circulars.

*V. TRANSACTIONS AND PROCEEDINGS OF SOCIETIES.

*W. MAGAZINES AND JOURNALS.
- A. American.
- B. British.
- Cz. Czech
- D. Dutch.
- F. French (language).
- G. German (language).
- H. Hungarian.
- I. Italian.
- P. Portugese.
- R. Russian.
- Sc. Scandinavian.
- Sp. Spanish.

*X. REFERENCE WORKS.
- a. Technical Aviation Handbooks.
- b. Year-Books.
- c. Dictionaries and Glossaries.
  - B. British.
  - E. Esperanto.
  - F. French.
  - G. German.
  - I. Italian.
  - L. Latin.
  - M. Multi-Lingual.
- d. Encyclopædias.
- e. Directories and Members' Lists.

Y. BOX-FILES.

(For list of files see Section II, under Y; for detailed list of contents see Section III.)

*Z. SUNDRIES.
- a. Aerial Time-Tables.
- b. Exhibition Catalogues.
- c. Firms' Catalogues.
  - A. Aeroplanes.
  - B. Engines.
  - C. Materials.
  - D. Various.
- d. Cigarette-Card Albums.
- e. Newspaper-Cuttings Albums.
- f. Flying-Display and Entertainment Programmes.
- g. Dinner Menus.
- h. Firms and Clubs (Prospectuses, Appeals for Funds, etc.).

SUBJECT INDEX: CROSS REFERENCES.

Subject.	Section Reference Letters.
Accidents	C.c., D.f.
Aerodromes	D.c.
Aerodynamics	A.a.
Aerofoils	A.a.
Aeroplanes	B.a., BB.a., BB.b.
Aircraft Carriers	B.d.
Air Forces	S.b., S.c.
Air Mail	D.b.
Airports	D.c.
Airscrews	BB.c.
Airships	C.a., C.d., C.e.
Air Transport	D.
Alloys	G.
Aluminium	G.e.A.
Animal Flight	B.f.
Autogiro	B.b.
Automatic Pilot	BB.f.
Balloons	C.a., C.c.
Bibliography	Q.
Biography	T.
Bird Flight	B.f.
Brass	G.e.B.
Chemistry	N.c.
Civil Aviation	D.
Congress Reports	OO.
Construction of Aircraft	BB.a., BB.b.
Copper	G.e.B.
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32 *ELLSWORTH, Lincoln. At the North Pole.* 1928. (Y.30.ii.24.)
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**34 *NOBILE, Umberto. Il Volo Transpolare.* 1925. (Also loan copy, T.c.30.)
35 *WELLMAN, Walter. The Polar Airship.* 1906. (pC.4/2.)

TT. FICTION AND ART.

a. Prose.

1 CARTER, J. L. J. Peggy the Aeronaut. 1910.
2 CHARLTON, L. E. O. The Next War. 1937.
3 GASTINE, Louis. War in Space (A Romance). 1913.
4 GOUVRIEUX, Mark. With Wings Outspread: a Romance of the War of 1920. 1916.
5 GRAHAME-WHITE, C., & HARPER, H. The Air King's Treasure. 1913.
6 GRIFFITH, G. The Syren of the Skies. (Undated—abt. 1910.)
7 HAGENBACH, A. Pilot Tex. 1935.
8 HOPE, Colin. Air Gold. 1935.
9 HUGHES, J. Scott. Ordeal by Air. 1930.
10 MARSH, R. The Flying Girl. 1916.
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12 SAINT - EXUPERY, Antoine de. Night Flight. 1939.
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15 ———————— The Air Patrol: a Story of the North-West Frontier. 1913.
16 "STREAMLINE." Foretold. 1934. (Short Stories.)
17 VERNE, Jules. The Clipper of the Clouds. 1887.
18 YEATES, V. M. Winged Victory. 1934.
19 DOMINIK, Hans. Der Wettflug der Nationen. 1933.
20 ———————— Ein Stern fiel vom Himmel. 1934.
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24 BERCKELAER, D. van. Howlers from Henlow. (Undated.) HUMOROUS CARTOONS.
25 KOERSS, Sophie. Der Jungflieger. 1927.
26 RYNIN, N. A. Visions, Legends, First Phantasies. 1928. IN RUSSIAN.
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**29 VERNE, Jules. Las Escursiones Aerostaticas. (Spanish Translation by Don Felipe de Burgos.) (Undated: 19th century.)
30 SAUNDERS, J. M. Wings. (GERMAN TRANSLATION.) Undated.
**31 JOHNSON, Dr. Samuel. The History of Rasselas. 1818.
32 MAITLAND, H. Lighter than Air. 1913. HUMOROUS. (See also TT.a.23.)
**33 VERNE, Jules. Cinq Semaines en Ballon. 1867.
34 *BEEMAN, S. W. The Great Day in* 1920. (*Anticipation of Air Warfare,* 1913.) (pR.1/16.)
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1 (Anonymous). The Loss of R.101. 1931.
2 BAKER, Charles B. Raftales. 1933.
3 BRANFORD, F. V. Titans and Gods. 1923.
4 DAY, Jeffery. Poems and Rhymes. 1925.
5 BERE, R. de la (Editor). Icarus: an Anthology of the Poetry of Flight. 1939.
6 HALL, E. Vine. In Full Flight. 1921.
7 (Anonymous). The Glider Pilot's Psalter. 1938.
8 GOWER, Pauline. Piffling Poems for Pilots. 1934.
9 TAYLOR, Leonard. Night Flight.
10 1939. (2 copies.)
11 MURRAY, Stella W. The Poetry of Flight: an Anthology. 1925.
12 RHOEN - ROSSITTEN SEGELFLIEGER. Rhön-Zauber: Segelflieger-Erinnerungen. 1931. (Light Verse about Gliding.)
13 *HERRIES, Paul Nethertон. (Pseudonym of Dr. F. W. Lanchester). The King's Prayer and other Poems.* 1936. (Y.25/29.)

c. Prints, Music, Sketches, Stamps, etc.

**1 LANDAUER, Bella. Some Aeronautical Music. 1933.
**2 ———————— Some Japanese Balloon Prints. (Undated.)
**3, 7 MARSH, W. Lockwood. Aeronautical Prints and Drawings. 1924. (2 copies.)
**4 BRUEL, F. L. L'Histoire Aéronautique par les Monuments: des Origines à 1830. 1909. (Reproductions of early Engravings, etc.)
**5 *FRANKENBURG, Kurt von. Luftfahrt-Kalender,* 1912.
**6 *SOCIETA DANTE ALIGHIERI. Leonardo da Vinci. (Special Stamp issued by the Society.)*
**8 *(COBHAM, A. J.) Special Mail Stamps commemorating London-Cape Town Flight of Alan J. Cobham.* 1925. *(Sheets of stamps, red and green, some perforated and others unperforated.)*
**9 VAULX, Comte H. de la, TISSANDIER, P., and DOLLFUS, C. L'Aéronautique des Origines à 1922. (Supplementary to BRUEL, TT.c.4.)

U. REPORTS OF RESEARCH INSTITUTIONS.

(For titles of individual Reports, see Section III.)

A. American.

1 Daniel Guggenheim Fund for the Promotion of Aeronautics. (Box-file Y.23.)

2 Astrophysical Observatory of the Smithsonian Institution. Annals, Vol. 3, 1913.

3 U.S. Bureau of Standards.
1. Technological Papers. (O d d Numbers.)
2. Scientific Papers. (Odd Numbers.)
3. Research Papers. (Odd Numbers.)

4 Air Corps Information Circular. No. 444, Nos. 572-649 (incomplete).

B. British.

1 Department of Scientific and Industrial Research. Reports: 1915/16-1918/19; 1920/21-1925/26; 1929/30.

2 National Physical Laboratory. Reports, 1916-39 inclusive (2 copies 1935). Abstracts of Papers: 1936, 1937, 1938. Inspection Programme: 1936, 1939.

3 Air Ministry.
1. Technical Memoranda: Nos. 18-22. 26, 28, 30. (1920-22.)
2. Aeronautical Abstracts f r o m Foreign Technical Press. (1920/23.)
Series III. Complete with Index (2 Vols.)
Series IV. Nos. 1-12 (without Index.) (2 Vols.)
Series V. No. 1 only.

**4 British Association for the Advancement of Science. Reports of Meetings.
1865—Birmingham.
1908—Dublin.
1913—Birmingham (incomplete: begins p. 84).
1914—Australia.
1915—Manchester.

C. British Empire.

1 National Research Council of Canada. Annual Report. 1934/5-1938/39 inclusive.

2 University of Toronto. Bulletins: Nos. 1-9 (1919-1932). New Series: No. 140 onwards. (No. 144 missing.) Note.—No. 140 (separate publication) follows No. 9 (collective volume containing reports up to No. 139).

3 Engineering Institute of Canada. Aeronautical Reprints, Nos. 1-9. 1931-38.

D. Czechoslovakia.

1 Institute of Military Aviation Studies, Prague. (Zpravy V o j e n s k e h o Leteckeho Ustavu Studijniho v Praze.) Reports: Nos. 1-19. 1927-32.) (No. 4 missing; 2 copies each of Nos. 6, 7, 13 and 16.)

E. Holland.

1 Rijks-Studiedienst voor de Luchtvaart, Amsterdam. Verslagen en Verhandelingen.
Part I. 1921.
Part II. 1923.
Part III. 1925.
Part VIII. 1939.

F. France (and French-Speaking Countries).

1 Chambre Syndicale des Industries Aéronautiques. Bulletin.
May-June, 1927.
May-June, July-Aug., Sept.-Oct., 1930.
March-April, July-Aug., Sept.-Oct., 1931.

2 Institut Aérotechnique de l'Université de Paris. Bulletin. (Nos. 1-3, bound together.) 1911.

3 Ministère de l'Air. Publications Scientifiques et Techniques. (Complete Series, to No. 161.)

4 Ministère de l'Air. Bulletins Scientifiques et Techniques. Series, Nos. 76-91.)

5 International Commission for Air Navigation. Official Bulletins (from No. 1, 1922, to No. 26, 1938.)

6 ———— Weekly Bulletin. (To May 1940; current year on Library Shelves; back numbers in stockroom.)

7a ———— Regulations concerning the Minimum Requirements for Airworthiness Certificates. 1931, 1933-38 inclusive.

7b ———— Regulations concerning the International Employment of Symbols and Terms used in Aeronautical Technology. 1935, 1936, 1938 Eds.

7c ———— Regulations for International Radio - Electric Service. 1931, 1934-38 inclusive.

7d ———— Regulations concerning the E m p l o y m e n t of Radiocommunication Apparatus. 1935, 1936, 1938 Eds.

7e ———— Convention relating to the Regulation of Aerial Navigation. 1939 Ed.

8 INTERALLIED AERONAUTICAL COMMISSION OF CONTROL. Rapport Technique. (Report on Ex-German Aerodromes and Material in Back and Occupied Areas.) 1919. Part I: Vols. 1 and 2 (1 set); Part II: Vols. 1, 2 and 3 (2 sets).

9 Service Technique de l'Aéronautique (BELGIAN). Bulletin: Nos. 5-18. (No. 12 missing.)

G. Germany (and German-Speaking Countries).

1 Aérodynamisches Institut an der Technischen H o c h s c h u l e Aachen. Abhandlungen, Nos. 1-16. (1925-33.)

2 Die Deutsche Seewarte. Archiv, Band 49, Nos. 9 and 10. 1931.

3 D.V.L. (Deutsche Versuchsanstalt für Luftfahrtforschung).
1. Tätigkeitsbericht. 1931 and 1934.
2. Jahrbuch. 1931, 1932, 1937 (2 copies), 1938 (2 copies).

4 Aerodynamische Versuchsanstalt zu Göttingen.
1. Ergebnisse: Vols. 1-4. (2 copies of Vol. 3.) 1923-32.
2. Technische Berichte. (Translated Abstracts IN ENGLISH, published by the Air Ministry; 2 Vols: A.P.1120 and 1121. 1925.)
3. Mitteilungen der Göttinger Modellversuchsanstalt. (Reprints from Z.F.M., 1910-1912.)

5 K. Preussisches Observatorium bei Lindenberg. Ergebnisse. 1900-1913 inclusive (1912 missing; special number 1908 deals with Ost-Afrika Expedition).

6 Technische Hochschule, Wien. (AUSTRIAN.) Beiträge zur Flugtechnik. 1937.

7 Technische Hochschule, Zürich. (SWISS.) Mitteilungen aus dem Institut für Aerodynamik. Nos. 4/5, 6, 7.

8 Z.W.B. (Zentralanstalt für Wissenschaftliches Berichtwesen).
1. Luftfahrt - Schrifttum des Auslandes. (German Translations of Foreign Technical Reports.) Vol. III, Nos. 8, 10 and 11. 1937.
2. Jahrbuch der deutschen Luftfahrtforschung. 1937, 1938 and Ergänzungsband 1938.

9 Internationale Kommission für Wissenschaftliche Luftfahrt. Internationale Beobachtungen. 1902-1912 inclusive. (1904 missing.)

10 Münchener Verein für Luftschiffahrt. Jahresbericht für das Jahr 1901.

11 W.G.L. (Wissenschaftliche Gesellschaft für Luftfahrtforschung.) Jahrbuch, 1921-26, 1929. Berichte und Abhandlungen, 1920-21.

12 Lilienthal - Gesellschaft. Jahrbuch: 1935, 1936, 1937. (Note.—The Z.W.B. Ergänzungsband to Jahrbuch 1938 represents the Lilienthal-Gesellschaft Transactions for 1938.)

13 Technische Hochschule, Stuttgart. Forschungsergebnisse, 1929.

H. **Italian.**

1 Società Aeronautica Italiana. Bolletino. 1905-1909 inclusive.

2 Stabilimento del Genio, Rome. Rendiconti. 1912-14. Continued as follows: Istituto Centrale Aeronautico: 1915-17; Istituto Sperimentale Aeronautico: 1920-22; Commisariato dell'Aeronautica: 1923-25; Ministero dell'Aeronautica, 1926-27.

3 Editoriale Aeronautica, Rome. Atti di Guidonia. Nos. 1-24.

4 R. Politecnico di Torino. Pubblicazioni. Nos. 101-130. (Note.—For previous numbers, and for No. 104, see box-file Y.28.)

5 R. Scuola Normale Superiore di Pisa. Annali, Serie II, Vol. II, Fasc. II. (Scienze Fisiche e Matematiche.) 1933.

J. **Polish.**

1 University Joseph Pilsudski, Warsaw. Reports. Nos. 1 and 2. 1938/39. IN POLISH.

2 Institut des Recherches de l'Aéronautique (Varsovie). (Instytut Badan Technicznych Lotnictwa.) Bulletin Nos. 6-21 inclusive. (1931/37.) (Text in Polish and French, interleaved.)

K. **Russian. (Imperialist and Soviet.)**

1 Institut Aérodynamique de Koutchino Bulletins, Nos. 1-5. (1906-14.) IN FRENCH.

2 Heavy Industries Centre: Aero Engines. (Ed. by P. I. BARANOV.) Publications, Nos. 1-20. (Incomplete.) IN RUSSIAN.

3 Central Aero-Hydrodynamical Institute of Prof. Joukowsky. Transactions, Nos. 1-283 (1925-36). (Incomplete.) IN RUSSIAN. Index in Russian and English at end of Series.

4 Moscow Institute of Transport Engineers. (Prof. DZHERZHINSKY.) Proceedings, Vols. XIV and XV (1929 and 1930). IN RUSSIAN.

5 Institute for Utilization of Energy. (Prof. KRZHIZHANOVSKY.) Publication No. 1. 1933. IN RUSSIAN.

6 Ukrainian Academy of Sciences. Pubcations Nos. 20, 21, 33, 34, 40. 1936-39. IN RUSSIAN.

L. **Asiatic Countries.** (In English, unless otherwise stated.)

1 Academia Sinica: The Academia Sinica and its National Research Institutes. 1931.

2 Harbin Polytechnic Institute, China. Journal and Transactions. Vol. 4, No. 1. IN RUSSIAN.

3 Institute of Physical and Chemical Research, Tokyo. Reports. (Series: in Progress. Latest Number received, No. 983.)

4 Tokyo Bunrika Daigaku: Science Reports. (Many in GERMAN.) (Series; latest Number received, No. 73.)

5 National Research Council, Tokyo. Japanese Journal of Engineering, Abstracts. (Published Annually.)

6 Aeronautical Research Institute, Tokyo University. Reports. (Series: latest Number received, No. 190.)

7 Science Reports of National Tsing-Hua University (China).

*UU. **NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. (U.S.A.)**

a. Technical Notes. Complete series: latest number received, No. 760. (Unbound copies may be borrowed.)

b. Technical Reports. Complete Series: latest number received, No. 682. (Unbound copies may be borrowed.)
c. Technical Memoranda. Odd Numbers: 411, 458, 482, 490, 511, 533, 544, 546. Series from No. 869 onwards: latest number received, No. 940. (Only Nos. 873-900 available for loan.)
d. Translations of Technische Berichte. Vol. III, Parts 1-7 inclusive. 1925.
e. Aircraft Circulars. Nos. 71, 74, 79, 84, 85, 90, 91, 94, 101, 103 and 105.

***V. TRANSACTIONS AND PROCEEDINGS OF SOCIETIES.**

1 American Society of Mechanical Engineers. Vols. 49-61 inclusive (1927-39.) (Duplicates of Vols. 57, 58, 59.)
2 Chartered Institute of Patent Agents. Vols. 46-56 inclusive. (1927-39.)
3 Institution of Automobile Engineers. Vols. 21-33 inclusive. (1926-39.)
4 Institution of Engineers and Shipbuilders in Scotland. Vols. 54-57, 61-74 inclusive. (1910-14, 1917-31.)
5 Institution of Mechanical Engineers. Series of unbound volumes from 1848 onwards kept in stock-room; bound volumes from 1925-39 on Library shelves. Also General Index, 1921-30 and Brief Subject Index: 1847-1926, '34, '36, '37 and '38 respectively.
6 Institution of Civil Engineers. Vol. 234 (1931-32), Vol. 239 (1934-35); Charter Centenary Celebration, June 3-7, 1928.
7 Institution of Naval Architects. Transactions, 1927-39 inclusive. Index (1926-30) and (1905-38).
8 Royal Society of Edinburgh. Proceedings, 1934-39 inclusive.
9 Institution of Aeronautical Sciences. Proceedings and Membership, 1933. (4 copies.)
10 Society of Mechanical Engineers, Japan. Reports, etc., kept in stock-room.
11 Junior Institution of Engineers. Journal and Transactions: 1926-27, 1927-28, 1929-30.
**12 Royal Aeronautical Society. Annual Reports: 1867-85, 1866-79 (2 copies), 1880-93.

***W. MAGAZINES. (Bound Volumes.)**

A. American.

1 Miscellaneous Early Magazines.
  1. Aero Club of America. Bulletin. (1912-15.)
  2. The Aeronautical World. 1902-3. (Discontinued.)
  3. Air Service Journal. 1917-18. (All Published.)
  4. Aircraft. Vol. 1, 1910. (All Published.)
  5. Fly. 1908-12. (In 2 Vols.) (Merged with "AERONAUTICS.")
  6. Flying. 1916. (Continuation of Bulletin of the Aero Club of America.)
  7. The Naval Flying Corps Monthly. 1917. (All Published.)
2 Aerial Age. 1915-22.
3 Aero. 1910-12; continued as Aero and Hydro. 1912-14.
4 Aviation. From 1916. (In Progress.) (Missing: Vol. 12, Jan.-June 1921; Vol. 28, Jan.-March 1930.)
5 Journal of the Aeronautical Sciences. From Vol. 1, 1934. (In Progress.)
6 Mechanical Engineering. 1931-35, 1937, 1938. (Other years, from 1923, in stock-room.)
7 Journal of the Society of Automotive Engineers. (S.A.E. Journal.) From Vol. 24, 1929. (In Progress.) (Missing: Vols. 26 and 27—1930.)
8 Aeronautics. 1907-15. (Vols. 1-16.) (Discontinued.)
9 Aero Digest. From 1926. (In Progress.)
10 U.S. Army Air Corps, Technical Data Digest. From March 1927. (In Progress, unbound.)
11 U.S. Patent Office Gazette.
12 U.S.A. Civil Aeronautics Journal.

B. British.

1 *Miscellaneous Early Magazines.*
  1. Aerial Observer. 1910-11. (Discontinued.)
  2. Air. 1916-17. (All Published.)
  3. The Aircraft Rag. 1917-18. (Discontinued.)
  4. Aircraft Supplies. 1917, 1918. (Discontinued.)
  5. Airship and Aeronautical Engineer. 1908-09. (Merged with The Aero.)
  6. B.P. Works Magazine. (Boulton and Paul.) Vols. 1 and 2. 1916-18. (All Published.)
  7. Ballooning and Aeronautics. 1907. (All Published.)
  8. Flighty. 1917-18. (All Published.)
  9. The Joystick. 1917. (Discontinued.)
  10. The Olympian. Vols. 1 and 2. 1917-19. (All Published.)
  11. The Piloteer. Vol. 2, 1917-18. (Discontinued.)
  12. Journal of the Royal Engineers. Vols. 8 and 9. 1908-09. (In Progress, unbound.)
  13. United Service Magazine. 1912-16.
  14. Whitecraft. 1917-18. (All Published.)
  15. The Aero Field. 1926-27. (Odd Numbers.)
2 Aeronautics. 1907—June 1921. (Discontinued in Aug. 1921.) Vol. 19 (July-Dec. 1920 missing; unbound odd copies of 1919-20 collected in file.)
3 The Aeroplane. From Vol. 1 (1911) to date.
4 Aircraft Engineering. From Vol. 1 (1929) to date.
5 The Airship. From Vol. 1 (1934) to date.
6 Airways. Vols. 2-9 (1926-32.)

7 The Engineer. From 1917 to date.
8 Engineering. From 1917 to date.
9 Flight. From Vol. 1 (1909) to date. (Vol. 16, 1924, missing.)
10 Flying. 1917-19. (All Published—merged in Airways.)
11 Journal of the Institution of Civil Engineers. (Current Year on Library shelves, back numbers in stock-room.)
12 Journal of the Institution of Electrical Engineers. From 1929 to date. (Missing: Vol. 69, 1931.)
13 Journal of the Institution of Engineers in Australia. Selected Papers 1929, 1930. (In Progress—unbound.)
14 Journal of the Institute of Transport. 1933-34, 1934-35. (In Progress—unbound.)
15 Journal of the Institute of Metals. From 1923 to date.
16 The Metallurgist. 1925-29. (Supplement to "The Engineer.")
17 Mond Nickel Co. The Nickel Bulletin. 1930 to date.
18 Royal Air Force Quarterly. From 1930 to date. (Missing: Vol. 5, No. 4—Oct. 1935.)
**19 Journal of the Royal Aeronautical Society. From 1897 to date. (Duplicate set on Library shelves.)
20 Journal of the Royal Meteorological Society. From 1923 to date. (Unbound.) (Missing: Vol. 49, No. 208—Oct. 1923; Vol. 54, Nos. 226 and 227—July and Oct. 1928.)
**21 Journal and Proceedings of the Royal Society of New South Wales. (From 1878 to 1927, incomplete; recent numbers, from 1931 onwards on Library shelves.)
22 The Aero. Vols. 1-7. 1909-13. (All Published.)
23 Aircraft. Vols. 1-4. 1916-19. (All Published.) (2 complete sets.)
24 Aircraft Production. Vol. 1 (1938/39). In Progress.
**25 Institution of Aeronautical Engineers. Journal. (2 Vols.)

Cz. **Czech.**

1 Miscellaneous Early Magazines. (None.)
2 Letectvi. From 1921 to outbreak of war, 1939. (1922 missing.)

D. **Dutch.**

1 Miscellaneous Early Magazines.
1. Avia. 1913, 1914.
2. De Luchtvaart. 1912, 1913.
2 Het Vliegveld. 1917, 1918, 1923 to 1933 inclusive. (Subsequent numbers in stock-room.)

F. **French (and French-Speaking Countries).**

1 Miscellaneous Early Magazines.
1. L'Aéro Mécanique. 1909-14. (Odd numbers in 1 Vol.) BELGIAN.
2. L'Autonautique. 1905-06. (Odd Numbers.)
3. Avia. 1909.
4. Aviation et Automobilisme Militaires. 3rd Year, Nos. 1-3. 1914. (Discontinued.)
5. Le Cerf-Volant. 1909/10, 1912/13, 1913/14. (Discontinued.)
6. La France Aérienne. 1897-1900. (In 1 Vol.)
7. Le Mois Aéronautique. Nos. 1-4. 1911. (Discontinued.)
8. Revue Aéronautique et Automobile. 1913/14.
9. Revue de l'Aéronautique. 1892-1901. (In 1 Vol.)
10. Revue de l'Aéronautique Militaire. 1910/11.
2 L'Aéronaute. 1868-1910. (Discontinued, Jan. 1911.) (Missing: 1881, '82, '85, '86, '87, '97, '98, 1908, '09.)
3 L'Aéronautique. From 1919 to date.
4 L'Aérophile. 1896/98 (in 1 Vol.).
5 L'Air. 1921, 1923-1926 inclusive.
6 La Guerre Aérienne. Nov. 1916-May 1919. (5 Vols.) (Title altered to "La Vie Aérienne" in 1919, ceased publication, 1922.)
7 La Revue Aérienne. 1908-14.
8 Revue de l'Aviation. 1906-13. (In 4 Vols.)
9 La Technique Aéronautique. 1910-14.
10 La Conquête de l'Air. 1913, 1914, 1922. (BELGIAN.) (In progress—unbound.)
11 Revue Aéronautique Internationale. 1931-36. (In 3 Vols.) (Subsequent issues in stock-room; suspended at outbreak of war, 1939.)
12 Revue Générale de l'Aéronautique. 1922-36. Nos. 1922-36. Nos. 1-20, bound in 5 Vols. (Missing: Nos. 3, 5, 11, 12, 15.)
13 La Science Aérienne. Vol. 1, 1932. (Subsequent numbers in stock-room.)
14 F.A.I. Bulletin. From 1927 to date.

G. **German (and German-Speaking Countries).**

1 Miscellaneous Early Magazines.
1. Deutsche Technik. 1912. (Incomplete—Discontinued.)
2. Flug- und Motor-Technik. 4th Year (Nos. 2-23.) 1910. AUSTRIAN.
3. I.L.A. Wochen Rundschau. (Paper issued during International Air Exhibition, Frankfurt-am-Main, 1909; unbound copies in file-case, incomplete.)
4. Luftflotte. 1908-13. (In 3 Vols., incomplete.)
5. Zeitschrift für Luftschiffahrt und Physik der Atmosphäre. 1894-1900. (In 4 Vols., incomplete.)
2 Flugsport. From 1920 to end 1939. (Temporarily suspended owing to War.)
3 Flugwoche. 1925 and 1926. (Other issues in stock-room.)
4 Illustrierte Aeronautische Mitteilungen. 1898-1909; afterwards entitled Deutsche Zeitschrift für Luftschiffahrt, 1910-11, and subsequently Deutsche Luftfahrer Zeitschrift. 1912-15. (Discontinued.)

5 Luftfahrtforschung. 1928-38. (Unbound copies of 1939 up to July in stock-room, temporarily suspended owing to War.)
6 Luftschiffer Zeitung. 1902-14. AUSTRIAN.
7 Luftwehr. 1934-38. (Unbound copies of 1939 up to July in stock-room, temporarily suspended owing to War.)
8 Luftwelt. 1934-39. (Temporarily suspended owing to War.)
9 Luftwissen. 1934-39. (Temporarily suspended owing to War.)
10 Oesterreichische Flugzeitschrift. 1911-14. (Ending at outbreak of Great War; duplicate volumes, incomplete, for 1911 and 1912.) AUSTRIAN.
11 Schweizer Aero-Klub Bulletin. 1906/07, 1910, 1912-18 inclusive. SWISS.
12 Z.F.M. (Zeitschrift für Flugtechnik und Motor-Luftschiffahrt.) 1912-16, 1921-33.

H. **Hungarian.**

1 Miscellaneous Early Magazines.
1. Aero. 1913 and 1914.

I. **Italian.**

1 Miscellaneous Early Magazines.
1. L'Aeronauta. 1896-99. (2 Vols.)
2. Navigazione Aerea. 1912/13.
3. Rivista Aeronautica. Nos. 1-10 in 1 Vol. 1916.
4. Rivista Italiana di Aeronautica. 1917.
2 L'Aerotecnica. Vol. 1 (1920 to date). (1926 unbound, 1 number missing.)
3 Ala d'Italia. Vol. 1, July-Dec. 1922. (Subsequent issues unbound in stock-room.)

M. **Miscellaneous.**

**1 Scientific. (Odd copies in Envelope File; see list in Section III.)
**2 Popular. (Odd copies in Envelope file; see list in Section III.)

P. **Portugese.**

1 Miscellaneous Early Magazines.
1. Revista Aeronautica (Bulletin of the Aero-Club of Portugal). 1911-17.

R. **Russian.**

1 Miscellaneous Early Magazines.
1. Technika Vozdushoplavania. (Technical Aeronautics.) 1913.
2. Vozdushoplavatel. (Aeronautics.) 1910.
3. Technika Vozdushoplavania. (2 odd numbers bound with various Russian pamphlets under Ref.: pR.7.)

Sc. **Scandinavian.**

1 Miscellaneous Early Magazines.
1. Svensk Motor Tidning. SWEDISH. 1912-14.

Sp. **Spanish.**

1 Miscellaneous Early Magazines.
1. Aviación. 1910.
2. Revista de Locomoción Aérea. 1909-11.
2 Revista Militar de Buenos Aires. 1934. ARGENTINE.

*X. REFERENCE WORKS.

a. **Technical Aviation Handbooks.**

1-4 MOEDEBECK, H. W. L. Pocket-Book of Aeronautics. (Translated by W. M. Varley.) 1907. 4 copies. (See also X.a.42.)
5 STAFF OF "THE MOTOR." Aero-Manual. 1909. (Also loan copy: R.c.199.)
6, 7 "FLIGHT" PUBLISHING Co. Flight Manual. 1910. 2 copies. (See also X.a.41.)
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73 KEMPE, H. R. Kempe's Engineer's Year-Book for 1931. (38th Ed.)
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75 ROYAL SOCIETY. Year-Book, 1939.
76-88 K.N.V.L. Jaarboekje. 1913, 1916, 1917, 1921, 1923, 1927, 1930, 1931, 1933-37 inclusive.
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92-105 HIRSCHAUER, L., and DOLLFUS, CH. L'Année Aéronautique. 1920-21—1932-33 inclusive. (3 copies of 1925-26; 2 copies each of 1927-28 and 1930-31.)
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131-132 NAGEL, A. P. (Editor). Automobile and Aero Year-Book. St. Petersburg, 1911 and 1912. IN RUSSIAN.
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3-7, 16, 19, 20 BRITISH STANDARDS INSTITUTION. Glossary of Aeronautical Terms. 1932 Ed. (2 copies), 1933 Ed. (3 copies), 1940 Ed. (1 copy advance proofs; 2 copies bound book.)
8, 9 ———————— British Standard Engineering Symbols. 1934. (2 copies.)
10 COLLINS, F. H. Authors' and Printers' Dictionary. 1933.
11 DOMMETT, W. E. Dictionary of Aircraft. 1915.
12, 13 FRIER, J. D. Definitions and Formulæ for Students: Aeronautics. 1930. (2 copies.)
14, 15 ROYAL AERONAUTICAL SOCIETY. Glossary of Aeronautical Terms. 1919. (2 copies.)
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1 AINSWORTH. Latin Dictionary. 1839.

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1 AHRENS, LOTHAR. Flugwesen Fünfsprachig. (German, French, English, Italian, Spanish.) 1939.

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17 BRITISH ALUMINIUM Co. Glossary of Technical Terms met with in the Light Metals Industry. (In English, French, German, Italian, Russian, Czech.) 1936.

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1-24 ENCYCLOPÆDIA BRITANNICA Co. LTD. Encyclopædia Britannica. 14th Ed., 1938. 24 Vols.

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37 VIVIEN, F. L. Vocabulaire de l'Aviateur Constructeur. 1911.

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e. **Directories and Members' Lists.**

1 AUTOMOBILE ASSOCIATION. A.A. Handbook. 1937-38.

2 ———— A.A. Foreign Touring Guide. 1932.

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4 AVIATION WORLD. Who's Who. 1911.
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6, 40 ENGINEERING. Engineering Directory, 1936 and 1938.
7, 8, 41 THE ENGINEER. Directory and Buyers' Guide. 1927, 1936-37, 1939.
9-12 FEDERATION OF BRITISH INDUSTRIES. Register of British Manufacturers. 1930-31, 1931-32, 1932-33, 1934-35.
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24 ORLOVIUS, Dr. H. POTURZYN, FISCHER v., and DRESEL, A. Transaer, 1937.
25-33 AIRWAYS PUBLICATIONS, LTD. Who's Who in British Aviation. 1931-36 Editions. (2 copies 1932.)
34 S.B.A.C. The British Aircraft Industry, 1939.
35 V.D.I. Ingenieur-Adressbuch. 1925.
36 ——— Mitglieder-Verzeichnis. 1928.
37 REICHSVERBAND DER DEUTSCHEN INDUSTRIE. Jahrbuch, 1938.
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39 ROYAL METEOROLOGICAL SOCIETY. List of Fellows. 1936.
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45 *PAN-RUSSIAN AERO CLUB. Members' List. (To March 2nd,* 1911.) (pR.7/11.)

C. **BOX-FILES.** (For contents of each File, see Section III.)

1 AERODYNAMICS. (See also Pamphlet Boxes PA.)
a. Aerodynamics.
b. Airscrew Theory.
c. Hydrodynamics.
d. Laboratories and Wind Tunnels.

2 AEROSTATICS. (See also Pamphlet Boxes PC.)
a. Kites.
b. Balloons.
c. Airships.
d. Parachutes.

3 AIRCRAFT TYPES. (See also Pamphlet Boxes PB.)
i. Up to 1918 (Alphabetical).
ii. After 1918 ,,

4 AIRPORTS. (See also Pamphlet Boxes PD.)
i. Descriptive Booklets.
ii. General Information.
a. Planning.
b. Lighting.

5 BIOGRAPHICAL DATA. (See also Pamphlet Box PT.1.) Alphabetical.

6 CIVIL AVIATION. (See also Pamphlet Boxes PD.)
a. Airways.
b. Progress of Civil Aviation.
c. Regulations.

7 ENGINES AND FUELS. (See also Pamphlet Boxes PEE and PF.)
a. General.
b. Oil and Turbine.
c. Fuels and Lubricants.
d. Engine Types (Alphabetical).

8 ENGINEERING. (See also Pamphlet Boxes PE.)
a. General.
b. Hydraulics.
c. Ground Engineering.

9 GENERAL INFORMATION. (See also Pamphlet Box PQ.1.) Alphabetical.

10 GLIDING AND SOARING, MODELS. (See also Pamphlet Boxes PB.4 and PB.6.)
a. Gliders.
b. Bird Flight.
c. Soaring (Theory).
d. Models.

11 HISTORICAL. (See also Pamphlet Boxes PR and bound volumes of Pamphlets pR.)
i. Up to 1903.
ii. 1904-13.
iii. 1914-18.
iv. 1919 onwards.

12 INSURANCE AND MEDICAL. (See also Box-files Y.22 and Y.23 and Pamphlet Box PL.3.)
a. Safety, Accidents, Insurance.
b. Medical.

13 MATERIALS. (See also Pamphlet Boxes PG.)
a. General Information.
b. Welding.
c. Specific Materials.

14 METEOROLOGY. (See also Pamphlet Boxes PJ and PK and bound volumes of Pamphlets PJ.)
a. General.
b. Stratosphere and Rocket Flying.

15 NAVIGATION. (See also Pamphlet Boxes PL.)
i. General.
a. Navigation.
b. Instruments.
c. Aircraft Markings.

ii. Navigation and Air Law. (Official Publications.)
iii. 1st and 2nd Class Navigators' Licence. (Examination papers, etc.)

16 PHOTOGRAPHY AND AIR SURVEY. (See also Pamphlet Boxes PL.2 and PL.4.)

17 WARFARE. (See also Pamphlet Boxes PS.)
a. Prior to 1914.
b. The Great War (1914-18.)
c. 1919 onwards. (Alphabetical.)

18 WIRELESS AND ELECTRICITY. (See also Pamphlet Boxes PM.)
a. Wireless.
b. Electricity.

19 AIR MINISTRY.
D.T.D. Specifications. (Kept up-to-date by checking against published list.)

20 AIR MINISTRY. (Official Reports.)
i. Air Estimates.
ii. Parliamentary Debates and Air Conference Reports.

21 BADEN - POWELL COLLECTION. (Works by Major B. F. S. Baden-Powell.) Alphabetical.

22 GUGGENHEIM AERONAUTICS LABORATORY.
Publications. (Incomplete Series.)

23 GUGGENHEIM FUND FOR THE PROMOTION OF AERONAUTICS.
Publications.

24 INTERNATIONAL TIN RESEARCH AND DEVELOPMENT COUNCIL.
Publications.

25 LANCHESTER COLLECTION.
(Works by Dr. F. W. Lanchester.)

26 NOBILE COLLECTION. (Works by General Umberto Nobile.)

27 ROYAL AIR FORCE.
i. General. (A.M. Pamphlets, Entry Regulations, etc.)
ii. Higher Education Test. (Syllabus, Examination Papers, etc.)

28 R. POLITECNICO DI TORINO.
Publications to No. 100. (Incomplete Series.) From 101 onwards (except 104 in this file) publications are on Library shelves under Ref. UH.4.

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30 SMITHSONIAN INSTITUTION, WASHINGTON.
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ii. Reprints.

31 UNIVERSITE DE LILLE. (Institut de Mécanique des Fluides.)
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32 WORLD ENGINEERING CONGRESS, TOKYO, 1929.

33 JUNKERS COLLECTION. (See also 11 boxes of Catalogues in stock-room.)

Z. SUNDRIES.

a. Time-Tables.

1 *LEP AERIAL BUREAU. Time-Tables and Information of European Airways.* 1925. (PZ.1/1.)

2, 6 *INTERNATIONAL AIR TRAFFIC ASSN. Aerial Time-Table. No.* 52, 1 *Aug.* 1925; *No.* 72, 1 *April* 1927. (PZ.1/2 and 6.)

3-5 *BROOK FLOWERS & CO. International Aerial Time-Table. No.* 1, *May* 1926; *No.* 2, *June* 1926; *No.* 12, *April* 1927. (PZ.1/3-5.)

7 *AERIAL A.B.C. LTD. Aerial A.B.C. No.* 6, *Aug.* 1929. (PZ.1/7.)

8 *BAYNARD PUBLISHING CO. Baynard A.B.C. of Air Services. May* 1934. (PZ.1/8.)

9 *ROADWAY PUBLICATIONS. Airway Time-Table. June* 1934. (PZ.1/9.)

10-13 DEUTSCHE LUFTHANSA. Reichsluftkursbuch. Summer, 1930; Spring, 1931; Summer, 1933; August, 1939.

14, 15 BRADSHAW. International Air Guide. No. 1, Nov., 1934; No. 52, February, 1939.

Also 8 Box-files containing paper folders as under :—
1. Belgium.
2. France.
3. Germany.
4. Holland.
5. Imperial Airways. (For other British Lines see No. 7.)
6. Italy.
7. Miscellaneous.
8. Northern Europe.

b. Exhibition Catalogues.

1 ROYAL HORTICULTURAL HALL. Model Engineers' Exhibition. 1909.

2 OLYMPIA. International Travel, Sports, Pastimes and Tropical Exhibition, 1909.

3-18 ——— Aero and Motor Boat Exhibition. 1909 (3 copies), 1910, 1911 (2 copies each), 1913, 1914 (3 copies), 1920 (4 copies), 1929.

19, 20 ASSOCIATION DES INDUSTRIELS DE LA LOCOMOTION AERIENNE. Exposition Internationale de Locomotion Aérienne, 1909 ; also 7e Exposition, 1921.

21-23 MINISTERE DE L'AIR. Exposition Officielle à Londres, 1929. 3 copies.

24 UNION SYNDICALE DES INDUSTRIES AERONAUTIQUES. XVIe Salon de l'Aviation, 1938.

25-28 INTERNATIONALE LUFTFAHRT AUSSTELLUNG, BERLIN, 1928. Conditions for Exhibitors; Catalogue (3 copies).

29 INTERNATIONAL MARITIME COLONIAL AND FLEMISH ART EXHIBITION, BRUSSELS, 1930. Britain at Antwerp. (Catalogue.)

30 IIe SALON INTERNATIONAL DE L'AERONAUTIQUE, BRUSSELS, 1939. (Catalogue.)
31 MILAN FAIR. Report on First International Aircraft Exhibition. 1935.
32 INTERNATIONAL AIR-POST EXHIBITION. Horticultural Hall, London. 1934.
33 EDITORIALE AERONAUTICA, ROME. La Prima Mostra del Volo nell'Arte Italica. 1939.
34, 35 BRITISH INDUSTRIES FAIR, 1937. Special Overseas Advance Edition of Catalogue : List of Exhibits (in 8 Foreign Languages).
36 MISCELLANEOUS (1900-14). Bound together in volume entitled "Pamphlets — International Aeronautics."
37 *SHELL-MEX, LTD. See how they fly.* (*Exhibition,* 1939.) (PZ.2/11.)

c. **Firms' Catalogues.** (Envelope Files.)

A. AEROPLANES.
1. American.
2. British (A—E, except De Havilland).
3. British. De Havilland.
4. British (F—Z).
5. Foreign (French, Dutch, Italian, Czech).
6. Foreign (German, except Junkers).
7. Foreign (German, Junkers).

B. AERO ENGINES.
1. American.
2. British.
3. Foreign (French, Italian, German).
4. Oil and Electric Engines.
5. Fuels and Lubricants.
6. Engine Parts and Accessories, Airscrews.

C. MATERIALS.
1. Alloys.
2. Concrete and Cement.
3. Plastics, Paint and Varnish.
4. Steel and Iron.
5. Tin.
6. Welding and Soldering.

D. GENERAL.
1. Heavy Industry (Cranes, Pumps, Hangar Equipment, etc.).
2. Aircraft Instruments and Measuring Instruments.
3. Electrical and Wireless Equipment.
4. Aircraft Components and Accessories.
5. Safety Apparatus.
6. Library and Office Equipment.

Also 11 boxes in stock-room containing JUNKERS Catalogues.

d. **Cigarette Card Albums.**

1, 2 CLUB ZIGARETTEN. Zeppelin-Weltfahrten. Vols. 1 and 2. 1932 and 1934.
3 DICKE SPORT ZIGARETTEN. Taschenbuch der Luftwaffe. (Abt. 1933.)
4 ORIENTALISCH MACEDONISCHEN CIGARETTEN FABRIK. Helden der Luft. (Abt. 1934.)
5 GARBATY CIGARETTEN-FABRIK. Die Eroberung der Luft. 1934.
6 SENIOR SERVICE CIGARETTES. Britain from the Air. 1939.
7-9 PLAYERS CIGARETTES.
Civil Aeroplanes.
Aircraft of the Royal Air Force.
International Air Liners.
(Undated—abt. 1935-37.)

e. **Newspaper Cuttings (Albums).**

1 Aeronautical (1783-1838).
2 Miscellaneous (1870); Aeronautical (1895-97) Indexed.
3 Aeronautical (1877-81).
4 F. W. Brearey (Lectures, etc.) (1876-1884).
5 Aeronautical (from 1884; nearly all undated).
6 Aeronautical (1894-96).
7 Aeronautical (1896).
8 Aeronautical (1906-14).
9 Miscellaneous (1907-11) Indexed.
10-12 Aeronautical (March-June, July-Aug. and Sept.-Nov., 1909) Indexed.
13-17 Aeronautical (1909—Dec., 1912) (5 Vols., same series).
18 Royal Aeronautical Society (Feb., 1909—June, 1915).
19 Institution of Aeronautical Engineers (1923-27).
20, 21 "Italia" Expedition (General Nobile), 1928-31. (2 Vols.)
22 Kites. (Baden-Powell Collection.)
23 Balloons (1789-1903). (Baden-Powell Collection.)
**24 Percy Pilcher (1896).
Also Series with own numbering :—
I—IV (Missing).
V. Aircraft in War; Meteorology, Navigation, Exploration. Jan.-June, 1913.
VI. Meetings, Exhibitions, Records, Legislation, Accidents. 1912.
VII. The Trade : 1913-15.
VIII. Miscellaneous : 1913-15.
IX. Aircraft in War . . . (etc.). July-Dec., 1913.
X. Meetings, Exhibitions . . . (etc.).
XI. Aircraft in War . . . (etc.). Jan.-June, 1914.
XII. Aircraft in War . . . (etc.). July-Oct., 1914.
XIII. Aircraft in War . . . (etc.). Nov., 1914—Feb., 1915.
XIV. Aircraft in War . . . (etc.). Feb.-Oct., 1915.
XV. The Society. July, 1915—June, 1918.
Also 2 unnumbered volumes "Aircraft in War," Oct., 1915—Oct., 1916.

Further cuttings classified in envelopes (alphabetical): from end of 19th century to Great War period, and a further series from 1921-26.

f. **Flying Display & Entertainment Programmes.**

3 BRISTOL AIRPORT. Official Opening, May 31st, 1930.
4 BIRMINGHAM AIRPORT. Official Opening, July 8th, 1939.
**5-8 LONDON AERODROME, HENDON. Season 1912 (2 copies), 1913, 1914. (Bound volumes : see also Z.f.20.)
9 BLACKPOOL AVIATION WEEK. Official Souvenir Programme. 1909.
10 INTERNATIONAL AIR RACES, DAYTON (Ohio). Oct. 2-4, 1924.
2, 11, 22 ROYAL AERO CLUB. Schneider Trophy Contest. 1929 (2 copies) and 1931.
12, 13 WHITE STAR LINES. Schneider Trophy Contest, 1931. R.M.S. " Homeric " Programme.
**14 ROYAL AERONAUTICAL SOCIETY. Garden Party, 14th May, 1939.
15, 29, 51 FLIGHT. King's Cup Air Race. 1936, 1937, 1938
**16, 17 S.B.A.C. Hatfield Flying Display and Exhibition. June 28 and 29, 1937. (Also loan copy, Z.f.24.)
18, 19, 32 ZUERICH : 4e MEETING AERONAUTIQUE INTERNATIONALE, 1937. (3 copies.)
**20 LONDON AERODROME, HENDON. Programmes, 1913-14, 1919. (Unbound copies.)
**21 MISCELLANEOUS. Programmes and Notices (prior to 1914) collected in box-file.
23 AERO CLUB OF AUSTRIA. 2e Internationale Oesterreichischer Alpenflug, 1935.
25 AERO CLUB OF SWITZERLAND. Internationales Flugmeeting, Zürich, 1937.
26 ROYAL AIR FORCE. Empire Air Day, 1938. (See also Z.f.39.)
27 DAILY EXPRESS. Air Display, Gatwick, June 25th, 1938.
28 LUTON AERODROME. Opening Display, 1938.
30 NATIONAL GLIDING CONTESTS, DUNSTABLE. July 9-17, 1938.
31 REDHILL AERODROME. Air Display, 29th July, 1939.
34, 35 *CANTERBURY FESTIVAL. Aviation Service, June 20th,* 1936. (PZ.2/2 and 3.)
36-38 *AERO CLUB OF AUSTRIA. Whitsun Flight,* 1936 *and* 1937 (2 *notices*). (PZ.2/4-6.)
39, 40 *ROYAL AIR FORCE. Empire Air Day, May* 29, 1937. (2 *copies.*) (PZ.2/7 and 8.) (See also Z.f.26.)
41-42 *ROMFORD FLYING CLUB. Women's Air Rally, July 9th,* 1938. (2 *copies.*) (PZ.2/9 and 10.)
43-50, 52, 53 ROYAL AIR FORCE. Hendon Display. 1921. (2nd copy under ref. 1, 33, PZ.2/1), 1926-29 inclusive, 1932, 1933, 1934, 1935, 1936, 1937.
**54-57 SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS. Hatfield Flying Display and Exhibition. Programmes for 1934, 1935, 1936 and 1937, bound in file case.

g. **Dinner Menus.**

**1 MISCELLANEOUS. Envelope file containing Menus and Guest Lists of Aeronautical Luncheons and Dinners.

h. **Firms and Clubs, Prospectuses, Appeals for Funds.**

**1 MISCELLANEOUS. Early notices of Company formations, appeals for funds, etc. (Envelope file.)

SECTION III.

Pamphlet and Periodical Literature.

(Pamphlets are arranged in their boxes in date order, the earliest at the bottom, separate sections in each box being divided by means of cardboard guides. Some newspaper cuttings of special interest have been included in the box-files. These are printed in italics and given a sequence number in the file but no other reference: they do not appear in the card-index or elsewhere in the catalogue.)

Pamphlet Boxes.

(Index Letters follow the Subject Headings of the main sections, with the addition of the prefix P.)

PA.1. **DYNAMICS.**

a. **Aerodynamics.**

1 1894 HELE-SHAW, Prof. H. S. Aerial Navigation.
2 1898 ZAHM, A. F. The Resistance of the Air determined at Speeds below 1,000 feet a Second.
3 1900 RAYLEIGH, Lord. On the Mechanical Principles of Flight.
3a, 3b 1904 BRYAN, G. H., and WILLIAMS, W. E. The Longitudinal Stability of Aerial Gliders. (2 copies.)
4 1904 ZAHM, A. F. Atmospheric Friction, with special reference to Aeronautics.
5 1904 ———————— Atmospheric Friction on Even Surfaces.
6, 7 1906 SAMUELSON, Arnold. Flight-Velocity. (2 copies.)
8 1909 HELE-SHAW, Prof. H. S. Aerial Automobilism.
9 1909 LARARD, C. E., and BOSWALL, R. O. An Aeronautical Model for Experimental Work.

10 1910 HELE-SHAW, Prof. H. S. Aeronautical Engineering.
11 1914 ———— Travelling at High Speeds on the Surface of the Earth and above it.
12 1918 SHAW, W. R. D. Technical Essays of an Aviator.
13 1919 ZAHM, A. F. Development of an Airplane Shock Recorder.
14 1920 ———— The Cross-Arm Wind-Balance.
15 1936 HOWLAND, R. C. J., and SHENSTONE, B. S. The Inverse Method for Tapered and Twisted Wings.
16 1936 RELF, E. F. Modern Developments in the Design of Aeroplanes.
17 1937 PIPER, R. W. Extensions of the New Family of Wing Profiles.
18 ?1937 HILL, G. T. R. Air Resistance and its Effect on Aeroplane Speeds.
19 1938 PIERCY, N. A. V. Aircraft Efficiencies.
20 1940 SIMMONS, N. Free Streamline Flow past a Vortex.

b. **Hydrodynamics.**

1 1898 HELE-SHAW, Prof. H. S. Further Experiments on the Character of Fluid Motion.
2 1899 ———— The Motion of a Perfect Liquid.
3 1914 RAYLEIGH, Lord. Fluid Motions.
4 1914 WILLIAMS, W. Ellis. On the Motion of a Sphere in a Viscous Fluid.
5 1933 PALSGROVE, G. K., and MORELAND, Wm. J. Variable Flow of Fluids.
6 1939 BAGNOLD, Major R. A. Interim Report on Wave-Pressure Research.

PA.2. **DYNAMICS.** (Quarto-Size Pamphlets.)

a. **Aerodynamics.**

1 1907 TURNBULL, A. W. Researches on the Forms and Stability of Aeroplanes.
2 1913 PETAVEL, J. E. Aeronautics.
3 1920 DRYDEN, Hugh L. Air Forces on Circular Cylinders, Axes Normal to the Wind, with special reference to Dynamical Similarity.
4 1924 MARTIN, H. M. The Elements of the Lanchester-Prandtl Theory of Aeroplane Lift and Drag.
5 1925 RICHARDSON, E. G. Critical Velocity of Flow Past Objects of Aerofoil Section.
6 1926 STANTON, T. E. On the Flow of Gases at High Speeds.
7 1927 PRANDTL, L., and BETZ, A. Vier Abhandlungen zur Hydrodynamik und Aerodynamik.
8 1928 MARGOULIS, W. Les Coefficients Caractéristiques des Turbo-Machines et des Machines Volantes.
8a 1928 TERAZAWA, K. On the Interference of Wind Channel Walls upon the Aerodynamical Characteristics of a Wing.
9 1929 TCHAPLIGUINE, S. A. On the General Theory of a Monoplane Wing : a Theory of Slotted Aeroplane Wing.
10 1930 BANERJI, Dr. S. K. The Effect of Indian Mountain Ranges on Air Motion.
11 1931 ROY, Maurice. Contribution à la Théorie des Ailes Sustentatrices.
12 1935 TAYLOR, G. I. Distribution of Velocity and Temperature between Concentric Cylinders.
13 1935 ———— Statistical Theory of Turbulence (Parts I and II).
14 1935 NEMENYI, Paul. A New Device for Direct Stream Field Studies and its Application.
15 1937 FENG, K. L. Airfoil Calibration Tests in the Tsing-Hua Wind-Tunnel.
16 1938 MOORE-BRABAZON, J. Some Considerations on the Reaction of Wind upon Sails.
17 1938 GREEN, J. J. Special Problems connected with the Take-off and Landing of Aircraft.

b. **Hydrodynamics.**

1 1915 BRYAN, G. H., and JONES, Robert. Discontinuous Fluid Motion Past a Bent Plane, with special reference to Aeroplane Problems.
2 1929 GOLDSTEIN, S. The Forces on a Solid Body moving through Viscous Fluid . . . (etc.).

c. **Wind Tunnels and Laboratories.**

1 1934 LE MAREC, G. La grande Soufflerie Aérodynamique de Chalais-Meudon (Seine-et-Oise).
2 1936 WATTENDORF, F. L. The Efficiency of Return Flow Wind-Tunnels.
3 1936 ———— (and Others). The Energy Ratio of the Tsing-Hua Wind-Tunnel.
4 1939 LEWIS, George W. Some Modern Methods of Research in the Problems of Flight.
5 1939 CAMBRIDGE INSTRUMENT Co. Wind-Tunnel Equipment (Blackburn Aircraft Ltd.).

PA.3. **DYNAMICS.** (Foreign.)

a. **French.**

1 1910 RAYBAUD, Paul. Les Aéroplanes (Considérations Théoriques).
2 1913 SEE, Alexandre. En quoi consiste la Stabilité.
3 1926 LETANG, M. Etude sur le Choix du Profil et de l'Allongement.
4 1926 DANIS, J. Notes sur une Forme du Champ Aérodynamique.

b. **German.**

1 1909 SAMUELSON, ARNOLD. Fluggeschwindigkeit. (2 copies English Version are in PA.1.)
2 1911 KARMAN, TH. VON. Ueber den Mechanismus des Widerstandes den ein bewegter Körper in einer Flüssigkeit erfährt.
3 1928 PFISTER, E., and PORGER, V. Tragflügeltheorie.
4 1931 PFISTER, E. Luftkräfte.
5 1932 KARMAN, TH. VON. Theorie des Reibungswiderstandes.

c. **Italian.**

1 1932 STIPA, L. L'Efficienza aerodinamica di Fusoliere tubolari.
2 1933 ———— Realizzazione dell' Aeroplano sperimentale a fusoliera tubolare.
3 ———— Il Presente e l'Avvenire dell'Aeroplano a Fusoliero tubolare.

PB.1. **AIRCRAFT TYPES.** (Official Handbooks.)

a. **Ministry of Munitions.**

1, 2 1918 H.597. Handbook on the Panther Ship Aeroplane. (2 copies.)
3 1918 H.641. A General Handbook on the Sopwith Torpedo Plane.
4 1918 HB.904. Handley Page Bomber Type 0.400 : Descriptive Handbook.

b. **Air Ministry.**

1 1924 A.P.595. Rigging Notes D.H.9a (400 h.p. Liberty).
2, 3 1922 A.P.877. Bristol Fighter F2B (Rolls-Royce Falcon III). (2 copies.)
4 1924 A.P.878. Handbook on the D.H.9a Aeroplane.
5 1922 A.P.905. Rigging Notes : F.5 Boat Seaplane.
6, 7, 8 1924 A.P.915. Avro Biplane Type 504.K. (3 copies.)
9, 10, 11 1922 A.P.916. Rigging Notes : Avro Biplane Type 504.K (100 h.p. Monosoupape). (3 copies.)
12 1925 A.P.1104. Rigging Notes : Armstrong Whitworth Siskin III (325 h.p. Jaguar).
13 1926 A.P.1206. Rigging and Maintenance Notes : Bison II (Lion Series V Engine).

PB.2. **AIRCRAFT TYPES.** (General.)

a. **Aeroplanes and Seaplanes.**

1 1918 BERGER-LEVRAULT (Publisher). L'Aéroplane des Frères Wright.
2, 3 1923 PARNALL & Co. Parnall Pixie Light Aeroplane. (2 copies.)
4 1930 VOGELSANG, C. W. Neue Flugzeuge.
5 1930 ———— Gross- und Riesenflugzeuge.
6 1932 STIPA, LUIGI. L'Ala a Turbina.

b. **Rotorcraft.**

1 1922 MARGOULIS, W. Les Hélicoptères.
2 1925 ACKERET, J. Das Rotorschiff.
3 1935 ETIENNE, PIERRE. Les Applications Militaires de l'Autogire. (Bound up with P. LEGLISE'S "L'Envol vertical de l'Autogire."
4 1935 CIERVA AUTOGIRO Co. The Autogiro. (A Synopsis of Information on the Principle.)

PB.3. **ANIMAL FLIGHT.**

a. **Birds and Animals.**

1 1874 PENAUD, ALPHONSE. Histoire de la Question du Glissement de l'Oiseau dans l'Air.
2 1909 CHANUTE, OCTAVE. Soaring Flight.
3 1919 AIR MINISTRY. Royal Air Force : Pigeon Service Manual.
4 1921 HANKIN, E. H. The Problem of Soaring Flight.
5, 6 1922 ———— Flying Fishes and Soaring Flight. (2 copies.)
7 1923 ———— and NORTH, J. D. On the Angle of Incidence in Soaring Flight.
8 1924 HANKIN, E. H. Soaring Flight.
9 1926 ———— The Evolution of Flying Animals.

b. **Mechanical Applications.**

1 1899 FITZGERALD, M. On Flapping Flight of Aeroplanes.
2, 3 1909 ———— On Flapping Flight. (2 copies.)
4 1913 MORDHORST, F. H. C. Das Naturgesetz des freien Schwebens der Vögel.
5 1925 BREGUET, LOUIS. Le Vol à Voile dynamique des Oiseaux.
6 1929 KAHN, LOUIS. La Propulsion Animale dans les Fluides; Possibilités d'Application au Vol à Vitesses variables.

PB.4. **GLIDERS AND GLIDING.**

1 1909 MORGAN, A. P. How to Build a 20-foot Biplane Glider.
2 ?1922 KEUTZER, A. Wie baue ich mir selbst Gleitflug-Apparat? (Hängegleiter.)
3 ?1928 SOARING FLIGHT Co. Sailplaning.
4, 5 1929 FISCHER, ARSENIUS. Zum Segelflugproblem. (2 copies, 1 of 1931 Ed.)
6 1931 DORSET GLIDING CLUB. Gliding, 1931. (Year-Book.)
7 1940 McCANN, BRYAN. Free Flight.

*PB.5. **AIRCRAFT RECOGNITION BOOKS.**

1 ?1915 AERONAUTIQUE MILITAIRE. Carnet de Silhouettes d'Avions Allemands.
2, 3 1915 ADMIRALTY (Air Dept.). Silhouettes of British, French and German Aircraft. (2 Editions.)
4 ?1915 AERONAUTIQUE MILITAIRE (?). Silhouettes d'Avions.
5 1915 ———— Annexe du Carnet de Silhouettes d'Avions Français.
6 1916 ———— Silhouettes d'Avions classés par Analogie.

7 1917 AIR MINISTRY (?). Silhouettes of Aeroplanes.
8 1917 AERONAUTIQUE MILITAIRE (?) Silhouettes d'Avions classées par Analogie.
9, 10 1919 CROSBY LOCKWOOD (Publisher). The Aircraft Identification Book. (2 copies.)
11 1940 THE AEROPLANE. Recognition Tests.
12 1940 ——————— Recognition Tests (Part 2).
13, 14 1940 ——————— Aircraft Identification (Friend or Foe?), Parts 1 and 2.
15 1940 HUTCHINSON & Co. German and Italian Aircraft.

PB.6. **MODEL AIRCRAFT.**

a. **Booklets.**

1 1930 VOGELSANG, L. W. Freifliegende Flugzeugmodelle : I, Motorlose Modelle.
2 ?1930 JACOBS, H. Hochleistungs-Motormodell und Enten-Modell.
3 ?1930 ——————— Leistungs-Segelflugmodell.
4 1929 STAMER, F., and LIPPISCH, A. Der Bau von Flugmodellen. (I, Für Anfänger.)
5 1930 ——————— Der Bau von Flugmodellen. (II, Für Fortgeschrittene.)
6 1931 WINKLER, H. Das Hochleistungs-Segelflugmodell.
7 1932 GOEPFERICH, W. Der Selbstbau eines Modelluftschiffes. (Zeppelin.)

b. **Constructional Plans.**

(Nos. 1-9: Series: Volckmanns Baupläne Flugfähige Flugmodelle.)

1 GENTSCH, O. Segelflug-Rumpfmodell.
2 SCHELHASSE H. F. A. Tiefdecker-Rumpfmodell.
3 SCHALK, E. Enten-Modell.
4 PRITSCHOW, W. Hochdecker-Rumpfmodell.
5 WINKLER, H. Schüler-Segelflugmodell.
6 SCHALK, E. Stabmodell mit Gummiantrieb für Anfänger.
7 WAECHTER, P. Flugdrachen in Vogel- und Flugzeugform.
8 POLZIN, G. Schulterdecker.
9 ADENAW, H. Nurflügel Hawx.
10 1940 AIR LEAGUE OF BRITISH EMPIRE. 19 Scale Plans of Modern British Aircraft.

PBB.1. **AIRCRAFT CONSTRUCTION AND PERFORMANCE.**

a. **Construction.**

1, 2 1918 PIPPARD, A. J. S., and PRITCHARD, J. L. Handbook of Strength Calculations. (H.B.806.) (2 copies.)
3 1924 ——————— Handbook of Strength Calculations. (A.P.970.)
4 1918 JUDGE, ARTHUR W. Fuselage Design.
5, 6 1930 VOGELSANG, C. W. Flugzeugbau. (Parts 1 and 2.)

b. **Performance.**

1 1916 WEISS, J., and KEITH, A. Notes on Giant Aeroplanes.
2, 3 1927 KERBER, L. V. A Proposed Standard Procedure for Computing Flight-Test Climb Data.
4 1939 HILL, Prof. G. T. R. Aeroplane Controls.

PBB.2. **AIRSCREWS AND PROPELLERS.**

a. **Ship's Propellers.**

(Nos. 1-12: Series: N.E. Coast Inst. of Engineers and Shipbuilders, April, 1938.)

1 1918 GEISSLER, R. Der Schraubenpropeller.
2 1938 BENSON, F. W. Propellers for Tugs and Trawlers.
3 1938 KEMPF, Dr. G. Further Model Tests on Immersion of Propellers: Effect of Wake and Viscosity.
4 1938 ALLAN, JAMES F. Aerofoil Sections in Screw Propellers.
5 1938 TROOST, L. Open Water Test Series with Modern Propeller Forms.
6 1938 GAWN, R. W. L. Effect of Shaft Brackets on Propeller Performance.
7 1938 HORN, Dr. F. Measurement of Wake.
8 1938 BAKER, G. S. The Qualities of a Propeller Alone and Behind a Ship.
9 1938 YAMAGATA, MASAO. Model Experiments on the Optimum Diameter of the Propeller of a Single-Screw Ship.
10 1938 DUNCAN, W. J. Torsion and Torsional Oscillation of Blades.
11 1938 KENT, J. L. Propeller Performance in Rough Water.
12 1938 THE ENGINEER (Magazine). Symposium on Propellers. (May 13, 1938.)

b. **Airscrews.**

1 1917 HODGSON, J. L. Tests on Model Propellers.
2, 2a, 3 1918 MINISTRY OF MUNITIONS. Handbook on Construction of Propellers. (3 copies.)
4 1928 PISTOLESI, E. Nuove Considerazioni sul Problema dell'Elica in un Vento laterale.
5 1931 STIPA, L. Esperienze con Eliche intubate.
6 1932 ——————— Sull'Impiego di Eliche di vario Tipo.
7 1938 HAMILTON-STANDARD PROPELLERS. H.S. Hydromatic Quick-Feathering Propeller.
8 1939 LAZZARINO, LUCIO. Studio sulle Eliche per Aeroplani Veloci.

PBB.3. **INSTRUMENTS AND APPARATUS.**

a. **Instruments.**

1 1924 AIR MINISTRY. Air Navigation Instruments. (A.P.803.)

1a 1929 ZUERN, JACKENROLL & Co. Flugzeug-Kompasse.
2 1936 ADMIRALTY. Manual of Sperry Gyro Compass, Addenda No. 1.
3 1936 SPERRY GYROSCOPE Co. Flying with the Sperry Horizon and the Directional Gyro.
4 1936 ———— The Sperry Gyropilot.

b. **Equipment and Apparatus.**
1 1924 ZAHM, A. F. The Vector-Ruling Protractor.
2-4 1925 AIR MINISTRY. Apparatus, Supplies Dropping, Marks 1 and 2. (A.P.1180.) (3 copies.)
5 1931 DEPT. OF THE INTERIOR, CANADA. The Aneroid Barometer and Altimeter.
6 1938 LIBRASCOPE DEVELOPMENT Co. The Librascope as Applied to Aircraft.

PC.1. **AEROSTATICS.**

a. **Kites.**
1 1910 LONDON BALLOON Co. Kite Drill.

b. **Balloons.**
1-4 1916 BREWER, GRIFFITH. Theory of Ballooning. (4 Lectures.)
5 1940 ———— Ballooning and its Application to Kite Balloons.
6 1940 ———— Some Kite-Balloon Experiments.

c. **Airships.**
1 1900 ZAHM, A. F. Some Theorems in the Mechanics of High-Speed Balloons (*i.e.*, Dirigibles).
2 1917 LIVERSEDGE, A. J. The Importance of the Large Airship.
3, 4 1917-18 ADMIRALTY (AIRSHIP DEPT.). Monthly Return of Items of Information. (Oct., 1917, and April, 1918.)
5 1926 HOVGAARD, WM. Adjustment of the Elastic Properties of a Model Keel : U.S. Army Airship RS-1.
6 1928 AIRSHIP GUARANTEE Co. R.100. (July 5th, 1928.)

d. **Parachutes.**
1 1891 FULLERTON, Capt. J. D. On Parachutes.
1a 1927 FRERI (S. A. BREVETTI). The Parachute "Salvator."
2 ?1929 IRVING AIR CHUTE Co. For Safety in the Air—Everywhere.
3 ? PAK PARACHUTE MANUF. Co. Parachute Pak (Service Manual).
4 1931 LUNDHOLM, C. H. The Robur Parachute.
5 1932 ———— Le Parachute "Corona."
6 ? BRITISH RUSSELL PARACHUTE Co. The British Russell "Lobe" Parachute.
7 ? BRITISH RUSSELL PARACHUTE Co. The British Russell "Lobe" Parachute: Maintenance and Packing Instructions.

PC.2. **AEROSTATICS.** (Foreign.)

a. **French.**
1 1882 GIFFARD, HENRY. Les Ballons Dirigeables à Vapeur.
2 1908 FAFIOTTE. Le Ballon Libre et sa Manœuvre.
3 1909 ASTRA, SOCIÉTÉ. Société de Constructions Aéronautiques "Astra."
4 1915 ETABLISSEMENT CENTRAL DU MATERIEL D'AEROSTATION MILITAIRE. Silhouettes des Dirigeables Françaises.
5, 6 1931 JOUX, ETIENNE. Un Dirigeable militaire "L'Adjudant - Vincenot" 1911-1916). (2 copies.)
7 1931 INNOVAZIONI AERONAUTICHE. Les Premiers 100 Aviateurs sauvés par le Parachute Salvator.

b. **German.**
1 1904 SILBERER, VICTOR. Der Stand der Luftschiffahrt zu Anfang 1904.
2 1914 ———— Warnende Stimmen in Bezug auf Zeppelin-Ballons.
3 1930 SCHWENGLER, Dr. Ueber die grosse Wirtschaftlichkeit des Luftschiffverkehrs.
4 1930 SEILKOPF, HEINRICH. Eindrücke und meteorologische Erfahrungen auf der Weltfahrt des Luftschiffs "Graf Zeppelin."
5 1936 LANGSDORFF, W. VON. L.Z.129, Hindenburg.

c. **Russian.**
1, 2 1926 VOROBIEFF, A. A Graphico-Analytical Method of Determining the Dynamic Height Attainable by Fully-inflated Airships. (2 copies.)

d. **Spanish.**
1 1911 SAMANIEGO. Los Dirigibles del Sistema Torres-Quevedo.

PD.1. **AIR TRANSPORT.**
1, 2 1919 MINISTRY OF RECONSTRUCTION. The Future of Aerial Transport. (2 copies.)
3 ?1920 HANDLEY PAGE, LTD. Aerial Milestones.
4 1920 CHATLEY, H. Commercial Aeronautics in China.
5 1923 INTERNATIONAL CHAMBER OF COMMERCE. Air Transportation.
6 ?1925 VERPLANCK, J. B. R. A Thousand Miles in a Flying Boat.
7 1926 AIR UNION. The First Air Line in the World.

8 1926 HARPER, HARRY. The Air Way (Imperial Airways).
9 1928 AMERICAN AERONAUTICAL CORPORATION. Air Transportation.
10 1928 DANIEL GUGGENHEIM FUND. Safety and Accommodation in European Passenger Planes.
11 1931 CARL BYOIR & ASSOCIATES. Graphic Facts about Aviation.
12, 13 1931 PIERCY, N. A. V. The Present Position in Aeronautics. (2 copies.)
14 1931 HUMPHERY, WOODS. Air Communications in Africa.
15 (a-e) ?1932 HUGHES, W. E. Chronicles of Icarus (Air Mail History), Nos. 1-5.
16 1938 THE AIR LEADER. (Advert. Booklet, with Civil Aviation Statistics.)
17 1938 SIKORSKY, IGOR. Science and the Future of Aviation.
18 1938 IMPERIAL AIRWAYS. Milestones.
19, 20 1939 GARCKE, STAMP & PERCIVAL. Comfort in Travel. (2 copies.)

PD.2. **CIVIL AVIATION.**

a. **Regulations and Control.**

1 1917 MONTAGU OF BEAULIEU. The World's Air Routes and their Regulation.
2 1920 CANADIAN GOVERNMENT. Air Regulations, 1920.
3 1926 DEPT. OF COMMERCE (U.S.A.). A Standard State Zoning Enabling Act.
4 1927 DANIEL GUGGENHEIM FUND. International Disarmament as related to the Development of Civil Aviation.
5, 6 1933-35 I.C.A.N. What the I.C.A.N. is. (2 copies.)
7 1937 AIR MINISTRY AND G.P.O. Empire Air Mail Scheme.
8 1937 AIR MINISTRY. Civil Air Transport Services.
9 1938 PRIMROSE, W. H., and TANGYE, N. The Correlation of Civil and Military Aviation.
10 1939 AIR MINISTRY. Report of the Committee on Control of Flying.
11 1939 ———————— Memorandum by Secretary of State for Air on above Report.
12 1939 ———————— Civil Air Transport Services (Imperial Airways).
13 1939 ———————— Civil Air Transport Services (British Airways).

b. **Economics.**

1 ?1934 DE HAVILLAND AIRCRAFT Co. The £ s. d. of Civil Aviation.
2 1923 AIR MINISTRY. Government Financial Assistance to Civil Air Transport Companies.
3 1923 ———————— Formation of Imperial Air Transport Company.
4 1924 ———————— Interim Report of Air Mails Committee.

PD.3. **AIR TRANSPORT AND CIVIL AVIATION.** (Foreign.)

a. **French.**

1 1926 COMITE FRANCAIS DE PROPAGANDE AERONAUTIQUE. L'Aviation Commerciale.
2 1926 VOLMERANGE, M. Le Trafic Aérien et la Sécurité.
3 1938 BONAME, R. La Place de l'Aviation commerciale française dans le Transport par Air mondial.

b. **German.**

1 1926 EVERLING, Dr. E. Um die Freiheit deutscher Luftfahrt.
2 1926 WEIGELT, Dr. K. Zusammenschluss im Luftverkehr.
3 1928 BLUM, O., and PIRATH, CARL. Lebensfragen der deutschen Luftfahrt.
4 1930 OSSWALD, Dr. EMMY. Zur Rationalisierung der innerdeutschen Handelsluftfahrt.
5 1930 "SILEX." Tausend Worte Lufthansa.
6 1932 NATIONALSOZIALISTICHE DEUTSCHE ARBEITERPARTEI. Korruption um Junkers.
7 1938 SCHNITZLER, REINHOLD. Luftverkehr.

c. **Other Languages.**

1 1928 INGENIŒRS VETENSKAPS AKADEMIEN. Flygtekniska Konferensen.

PD.4. **AIRPORTS.**

a. **Planning.**

1 1923 AIR MINISTRY. Report on Aerodrome Facilities of London.
1a 1924 HAMILTON, Major R. Hangar Erection in Iraq.
2 1930 MACDONALD, A. F. Airport Problems of American Cities.
3 1933 LEWIS-DALE, H. A. The Construction of Aerodromes.
4 1934 U.S. DEPT. OF COMMERCE. Airport Grading and Drainage.
5 1939 SCHIPHOL AIRPORT. Amsterdam : Sea and Airport.

b. **Lighting.**

PD.5. **CIVIL AVIATION.** (James Jackson Cabot Lectures.)

1 1937 WARNER, E. P. The Early History of Air Transportation.
2, 3 1938 IDE, JOHN JAY. International Aeronautic Organisations and the Control of Air Navigation. (2 copies.)
4, 5 1939 LEDERER, JEROME. Safety in the Operation of Air Transportation. (2 copies.)
6 1940 ZANDT, J. PARKER VAN. European Air Transport on the Eve of War : 1939.

PE.1. **ENGINEERING.** (Theory.)

a. **General.**

1 1916 CONSTANTINESCO, G. Wave Transmission.
2 1923 FOWLER, Sir HENRY. Transport and its Indebtedness to Science.
3 1927 OGILVIE, ALEC. Application of Power to Air Transport.
3a 1933 POSEY, CHESLEY J. Tests of Anchorages for Reinforcing Bars.
4 1934 APPLIED MECHANICS. Programme of 4th International Congress.
5 1937 IMPERIAL COLLEGE, KENSINGTON. Research financed from Clothworkers' Company's Grant, 1937-38.
6 1939 KERR, P. Tank Strapping.

b. **Structures.**

1 1914 INGLIS, CHARLES E. Examples in Applied Mechanics and Elementary Theory of Structures.
2 1925 PIPPARD, A. J. S., and BAKER, J. F. On the Experimental Verification of Castigliano's Principle of Least Work . . . (etc.).
3 1938 MARGUERRE, K. Die Durchschlagskraft eines schwach gekrümmten Balkens.

c. **Hydraulics.**

1 1934 QUINONES, MIGUEL A. An Investigation of the Performance of Large Centrifugal Pumps using Air as a Medium..

PE.2. **ENGINEERING.** (Practical.)

a. **Ground Engineering.**

1 1915 ROYAL NAVAL AIR SERVICE. Aircraft : Instructions for Care and Maintenance.
2 1916 ——————— Instructions for Inspecting Officers of Aircraft under Construction.

b. **Careers.**

1 ?1937 DE HAVILLAND, Capt. G. Aeronautical Engineering and Commercial Aviation.
2 1937 AUSTIN, Sir HERBERT. Automobile Engineering.
3 1937 HUMPHREYS, C. L. HOWARD. Civil and Municipal Engineering.
4 1933 MINISTRY OF LABOUR. Engineering. (Choice of Career Series, No. 16.)
5 ?1936 LORD HIRST OF WITTON. Electrical Engineering.
6 1939 HALL, H. SCOTT. Commercial Vehicle Selling as a Career.
7 ?1937 REDWING SCHOOL OF FLYING. Courses of Training for Aircraft Engineers and Pilots.
8 ?1935 HENLY'S, LTD. Free Flying Course to Purchasers of Aircraft.

PE.3. **ENGINEERING.** (Institution of Civil Engineers.)

a. **Selected Engineering Papers.**

1 1925 (No. 24) NAYLOR, THOS. M. Whirling Speeds of Loaded Tapered Shafts
2 1930 (No. 101) BATEMAN, E. H. The Transverse Vibrations of a Simple Strut.
3 1931 (No. 113) NAYLOR, THOS. M. Whirling Speeds of Shafts supported in Multiple Bearings.
4 1932 (No. 128) ORR, JAMES. The Torsional Properties of Structural and other Sections.

b. **Excerpts from Journal.**

1 1922 (No. 4405) BAIRSTOW, L., and PIPPARD, A. J. S. Torsional Stresses in a Shaft of any Cross-Section.
2 1936 (No. 5062) PIPPARD, A. J. S., and SPARKES, S. R. Simple Experimental Solutions of Certain Structural Design Problems.
2a 1937 (5076) NICHOLS, H. J. Pre-Stressing Bridge Girders.
3 1936 (No. 5108) PIPPARD, A. J. S., TRANTER, E., and CHITTY, L. Mechanics of the Voussoir Arch.
4 1938 (No. 5127) BURNS, R. V., and WHITE, C. M. The Protection of Dams, Weirs and Sluices against Scour.
5, 6 1938 (No. 5145) PIPPARD, A. J. S. An Application of the Principle of Superposition to Certain Structural Problems. (2 copies.)
7 1938 (No. 5176) PIPPARD, A. J. S., and DE WAELE, J. P. A. The Loading of Inter-Connected Bridge Girders.
8 1939 (No. 5177) PIPPARD, A. J. S., and ASHBY, R. J. An Experimental Study of the Voussoir Arch.
9 1939 (No. 5211) HARLEY-MASON, J. H. Reconstruction of the Aldgate East Station.

c. **Miscellaneous Publications.**

1 1936 GIBB, Sir ALEXANDER. Engineers and Empire Development. (Presidential Address.)
2, 2a 1930 SOUTHWELL, Prof. R. V. Aeronautical Progress, 1914-1930. (James Forrest Lecture.) (2 copies.)
3 1939 HINDLEY, Sir C. D. MAGGS. Presidential Address.
4 1938 RESEARCH COMMITTEE. Report for 1935-36 and 1936-37.

PEE.1 **ENGINES.** (Types.)

1 1909 ANZANI, A. Advertisement Booklet, 1909-10.
1a 1912 CLARK, A. GRAHAM. Aeronautical Engines.
2 1916 WOLSELEY MOTORS, LTD. Care and Maintenance of "Wolseley-Renault" Aviation Engines.
3 1917 ——————— Care and Maintenance of "Wolseley-Hispano-Suiza" Aviation Engines, W.4A and W.4B Types.
4 1917 ——————— Care and Maintenance of "Wolseley-Hispano" Aviation Engines, "Viper" (W.4A*) Type.

5 1919 CABLE, Boyd. Rolls-Royce Aero Engines.
6 1924 HISPANO-SUIZA, Société. Advertisement Booklet.
7 1926 FIAT AVIATION. Advertisement Booklet.
8 1926 BRISTOL AEROPLANE Co. "Bristol Lucifer" Series III.A Engine.
9 1929 ——————— "Bristol Jupiter" Radial Air-cooled Aero Engine.
10 1931 CIRRUS-HERMES. Cirrus (Mark III) 85/95 h.p. Engine.
11 1932 ——————— Cirrus Hermes II, 110/118 h.p. Engine.
12 ? BRITISH SALMSON AERO ENGINES. Salmson Engine Type 9 A.D., 40 h.p.

PEE.2. **ENGINES.** (Theory.)

1 1913 CASE, John. Elementary Theory of Heat and Heat Engines.
2 1916 LEGROS, L. A. Presidential Address (to Institution of Automobile Engineers).
3 1926 LEHR, G. Note sur les Moteurs d'Aviation à Came ou en Barillet.
4 1931 ZUCK, H. E. Engine Performance at High Compression Ratios.
5 1934 WILKINSON, G. S. Aero Engine Design.
6 1936 SANGER, F. J. Some Recent Developments in Internal Combustion Engines.
7 1936 HAUTTMANN, H. The Relation of Laboratory Research to Engine Design.

PEE.3. **ENGINES.** (Ignition, Carburation, Components.)

a. **Carburettors.**

1 ? CLAUDEL-HOBSON. Aero Carburettor. (A.1, 48A.)
2 ? HOBSON (AIRCRAFT & MOTOR COMPONENTS Ltd.). The Hobson Master-Control System for Aircraft Engines.

b. **Magnetos.**

1 1930 BRITISH THOMSON-HOUSTON Co. Type AG4 Magnetos. (Instruction Booklet 1407.)
2 ? FARMAN, Société. Notice sur le Démarreur "Farman" à Cartouche.

c. **Components and Accessories.**

1 ? MELLANBY, Prof. A. L. Engineering Valves.
2 ? SCHOLES, Prof. G. E. Power Plant Auxiliaries.
3 1931 MAURER, Edward R. Friction of Some Babbitt Roller and Ball Bearings.
4 ? FARMAN, Société. Les Compresseurs Farman et la Suralimentation des Moteurs d'Avions.
5 ? WELLWORTHY PISTON RINGS, Ltd. Points on Piston Rings.
6 1939 FEDDEN, A. H. R. The Development of the Monosleeve Valve for Aero Engines.

PEE.4. **ENGINES.** (Non-Petrol.)

a. **Oil Engines.**

1 1932 CHORLTON, Alan E. L. Oil Engine Traction.
2 1933 DICKSEE, C. B. Compression-Ignition Engines.

b. **Turbines.**

1 1926 GUIDONI, Alessandro. Turbomotore a Compressore a Nafta.

PF.1. **FUELS AND LUBRICANTS.**

a. **Fuels and Fuel Systems.**

1 1921 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Fuel for Motor Transport (2nd Memo. of Fuel Research Board).
2 1930 HASLAM, R. T., and RUSSELL, R. P. Hydrogenation of Petroleum.
3 1934 FAIGENBAUM, H. M. (and Others). Variations in Service Station Gasoline.
3a 1936 INST. OF MECHANICAL ENGINEERS. Symposium of Papers on Fuel Injection Equipment. (Articles by J. F. ALCOCK, S. H. ATTWOOD, S. J. DAVIES, A. F. EVANS, V. H. F. HOPKINS, C. W. LAWSON, A. W. ROWE.)
4, 5 1937 BANKS, F. R. Some Problems of Modern High-Duty Aero Engines and their Fuels.
6 1939 LANGLEY, M., and BARLOW, H. M. Static Electricity in Relation to Refuelling in Flight.
7 1940 LANGLEY, M. Landing Speed and Ceiling in Relation to Refuelling in Flight.

b. **Lubricants.**

1 1920 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Report of the Lubricants and Lubrification Inquiry Committee.
2 1934 ——————— A Study of the Boundary Lubricating Value of Mineral Oils of Different Origin.
2a 1935 REDGROVE, E. R. The Boundary Friction of Oxidised Lubricating Oils.
3 1938 ACHESON, E. G. (Ltd.). The Lubrification of New Reduction Gears with "Dag" Colloidal Graphite.
4 1938 ——————— The Lubrification of Air Compressors and Blowers with Oil containing "Dag" Colloidal Graphite.

PG.1. **MATERIALS.** (General Information.)

1 1906 HADFIELD, R. A. Unsolved Problems in Metallurgy.
2 1912 HOPKINSON, Prof. B. The Pressure of a Blow.
3 1917 BARRY, Sir J. Wolfe. The Standardisation of Engineering Materials.

4 1922 STROMEYER, C. E. Fatigue of Metals.
5 1922 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Deterioration of Structures in Sea-Water.
6 1928 TURNER, T. HENRY. Fighting Corrosion.
7, 8 1928 PY, GAËTAN. Progrès de la Métallurgie et leur Influence sur l'Aéronautique. (2 copies.)
9 1931 ROSENHOLTZ, J. L., and SMITH, D. T. Tables and Charts of Specific Gravity and Hardness for Use in the Determination of Minerals.
10 1933 PERLENFEIN, A. A Chromium Plating Bath with the Fluoride Ion.
11 CARPENTER, Sir H. Metals in the Service of Human Life and Industry.
12 1933 DAYTON, RUSSELL W. An Investigation of Methods of Decarburising Iron-Nickel-Chromium Alloys.
13 1936 NATIONAL PHYSICAL LABORATORY. Physical Constants of Pure Metals.
14 1939 SHAW, HARRY. Metal-Sprayed Bearings for High-Speed Operation.
15 1939 FROMMER, LEOPOLD. The Estimation of Cold-Work from X-Ray Diffraction Patterns.

PG.2. **MATERIALS.** (British Standard Specifications.)

1, 2 1928 B.S. Tables of Pipe Flanges (for Land Use). (B.S.I. Ref. : No. 10, Part I.)
3 1938 Tensile Testing of Metals. (B.S.I. Ref. : No. 18.)
4 1931 Airscrew Hubs and their Fixings. (I : Hubs.) (B.S.I. Ref. : No. 87, Part I.)
5 1920 Cold-Worked Steels for Aircraft. (B.S.I. Ref. : No. 112.)
6 1920 Sheet Steels for Aircraft. (B.S.I. Ref. : No. 113.)
7 1934 Tests on Thin Metal Sheet and Strip. (B.S.I. Ref. : No. 485.)
8 1933 Nomenclature of Timber for Aircraft Purposes. (B.S.I. Ref. : No. 491.)
9 1932 A Guide to Aerodrome Lighting. (B.S.I. Ref. : CC(ELG) 7631.)
10, 11 1934 Land Aerodrome and Airway Lighting (and 1 copy 1937 Ed.). (B.S.I. Ref. : No. 563.)
12 1938 Synthetic Resin (Phenolic) Moulding Materials and Mouldings. (B.S.I. Ref. : No. 771.)
13 1939 Testing of Fans for General Purposes. (B.S.I. Ref. : No. 848.)
14 1940 Dimensions of Instrument Jewels. (B.S.I. Ref. : No. 904.)
(See also Series of Specification Sheets collected in two book-files : Ref. G.b 3 and 4.)

PG.3. **MATERIALS.** (Aluminium, Brass and Copper.)

a. **Aluminium and its Alloys.**

1 1924 ANDERSON, R. J., and BOYD, M. E. The Production of Aluminium-Alloy Pistons in Permanent Moulds.
2 1924 ANDERSON, R. J., and BOYD, M. E. Salvage and Reclamation of Aluminium Alloy Castings by Soldering and Welding.
3 1924 GUILLET, L. A New Aluminium Alloy—Alpax.
4 1926 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. The Anodic Oxidation of Aluminium and its Alloys as a Protection against Corrosion.
5 1927 BRITISH ALUMINIUM Co. LTD. Aluminium Sections and Matting.
6 1930 ——————— Powdered and Granulated Aluminium.
7 1930 MORTIMER, GEORGE. Wrought Alloys of Aluminium in Aircraft.
8 ? ALUMINIUM (II) LTD. "Alclad": a New Corrosion-resistant Aluminium Product.
9 ? ——————— Commercial Forms and Applications of Aluminium and Aluminium Alloys.
10 ? ——————— Some Aspects of the Commercial Manipulation of Aluminium.
11 ? JAS. BOOTH & Co. (1915) LTD. D.2 (Aluminium-Magnesium Alloy).
12 1930 BRITISH ALUMINIUM Co. LTD. Aluminium Facts and Figures. Supplementary Sheets. (ORIGINAL MISSING.)
13 1940 ARROWSMITH, J. A., and WOLFE, K. B. The Use of Refrigeration for Delaying the Age-Hardening of Duralumin Type Alloys.

b. **Brass, Bronze and Copper.**

1 1935 COPPER DEVELOPMENT ASSOCIATION. Copper-Steels to Resist Corrosion.
2 1937 NEAVE, D. P. C. Copper and its Alloys in Automobile Design.
3 1938 COPPER DEVELOPMENT ASSOCIATION. Copper Alloys in Engineering.
4 1939 ——————— Lead-Bronze Bearings.
5 1936 MILLER, H. J. High-Tensile Strength Brasses or "Manganese Bronzes."
6 1933 JAS. BOOTH & Co. (1915) LTD. Brass and Copper. (Tubes, Sheets, Strip Rods, Sections.)
7 1932 ——————— Brass and Copper : Table of Weights and Gauges.
8 1940 TAYLOR, H. G. The Resistance of Copper to Soil Corrosion.

PG.4. **MATERIALS.** (Nickel; Non-Ferrous Metals.)

a. **Nickel.**

1 1927 FARIS, C. H. The Uses of Nickel Deposits for Engineering Purposes.
2 1935 EVEREST, A. B. Nickel Alloys in the Papermaking Industry.
3 1936 STANLEY, R. C. The Nickel Industry in 1936.

4, 5 1936-37 IMPERIAL SMELTING CORPORATION LTD. Cadmium Nickel (NS.5) Bearing Metal. (2 copies, 1 of revised Ed., 1937.)

b. **Non-Ferrous Metals.**

1 1926 BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION. Seventh Annual Report.
2 1933 ———— Fourteenth Annual Report.
3 1937 BAKER, W. A. Creep of Non-Ferrous Metals and Alloys.
4 1937 WATERHOUSE, H. The Properties of Lead and Lead Alloys. (Fatigue Resistance.)
5 1938 PEARSON, T. F. Nickel Silver.
6 1939 HOEFFDING, Dr. OLEG. Die Nicht - Eisen - Metallwirtschaft der Sowjetunion.
7 1939 TWYMAN, F. Industrial Application of Spectography in the Non-Ferrous Metal Industry.

PG.5. **MATERIALS.** (Plastics, Fabrics.)

a. **Plastics.**

1 1937 AXILROD, B. M., and KLINE, G. M. Study of Transparent Plastics for Use on Aircraft.
2-5 1937 INSTITUTE OF THE PLASTICS INDUSTRY. Transactions, Jan., 1937, and June, 1937. (2 copies each.)

b. **Fabrics, Dopes and Adhesives.**

1 1926 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. 2nd Report of the Adhesives Research Committee.
2 1930 ———— 2nd Report of the Fabrics Co-ordinating Research Committee.
3 1932 ———— The Viscosity of Cellulose Solutions.

PG.6. **MATERIALS.** (Iron and Steel.)

1 1885 MACKINLAY, Major G. Mild Steel Applied to Naval and Military Purposes.
1a 1905 HADFIELD, R. A. Presidential Address (to Iron and Steel Institute).
2 1913 ARNOLD, Prof. J. O. Recent Advances in Scientific Steel Metallurgy.
3 1915 HADFIELD, Sir R. A. History of the Metallurgy of Iron and Steel.
4 1919 PHILPOT, Capt. H. P. Some Experiments on Notched Bars.
5 1924 BAGNALL-WILD, R. K. Notes on Iron and Steel.
6 1931 HADFIELD, Sir R. A. Notes on a Research regarding Faraday's "Steels and Alloys."
7 ? HADFIELD'S, LTD. Hadfield's "Hecla" and "Era" Steels for Use in Diesel Engine Construction.
8, 9 1935 HATFIELD, Dr. W. H. Stainless Steels. (2 copies.)
10, 11 1936 ———— Heat-, Rust- and Acid-Resisting Steels. (2 copies.)
12 1939 NEWELL, W. C. The Vacuum Fusion Method for the Determination of Oxygen in Steel.
13 1939 HATFIELD, Dr. W. H. A Study of a Nickel-Chromium-Molybdenum-Vanadium Steel Ingot.
14 1939 STANFIELD, G. Quenching Tests in Various Media.

PG.7. **MATERIALS.** (Rubber and Miscellaneous.)

a. **Rubber.**

1 1926 MORRISON, I. F. On the Mechanical Properties of Rubber Cord.
2 1929 RUBBER GROWERS' ASSOCIATION. Report upon the Relative Vibration-Absorptive Properties of Certain Types of Rubber.
3 1930 ———— Rubber in Aircraft Design.
4 1933 STEVENS, H. P. and W. H. Rubber Latex.
5 1937 MACBETH, COLIN. Rubber in Automobiles.

b. **Miscellaneous Metals and Minerals.**

1 1909 DAINS, H. H. The Indian Magnesite Industry: Magnesite, its Preparation and Uses.
2 1937 JAS. BOOTH & Co. Notes on the Working, Welding and Machining of Wrought Elektron Products.

PG.8. **MATERIALS.** (Timber.)

1 1934 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Report of the Committee on the Mechanical Testing of Timber.
2 1937 ———— Methods of Bending Wood by Hand.
3 1937 SCIENCE MUSEUM. An Outline of the Structure, Properties and Utilisation of Timber.
*4 1938 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Report of the Forest Products Research Board for the Year 1937.
5 1938 ———— Recent Work on Moisture in Wood.
6 1938 ———— Machinery and Equipment Used for Bending Wood.
7 1938 ———— Kiln-Drying Schedules.

PG.9. **MATERIALS.** (Committee Reports, Welding.)

a. **Springs Research Reports.**

1 1928 HANKINS, G. A. The Endurance of Spring Steel Plates under Repetition of Reversed Bending Stress.
2 1928 ———— Torsional Fatigue Tests on Spring Steels.
3 1928 SWAN, A., and SAVAGE, L. G. The Surging of Engine Valve Springs.
4, 5 1931 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Report of the Springs Research Committee. (2 copies.)

b. **Gas Cylinders Reports.**

1 1926 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. 2nd Report. Periodical Heat Treatment.
2 1929 ——————— 3rd Report. Alloy Steel Light Cylinders.

c. **Welding.**

1 1912 STANTON, T. E., and PANNELL, J. R. Strength and Fatigue Properties of Welded Joints in Iron and Steel.
2 1922 AIR MINISTRY. Oxy-Acetylene Welding. (A.P.880.)
3 1935 ACETYLENE, OXY-ACETYLENE WELDING AND ALLIED INDUSTRIES. 12th International Congress, London, 1936. (Regulations.)
4 ? ALUMINIUM, LTD. The Welding of Aluminium.
5 ? JAS. BOOTH & Co. Hints on the Welding of MG7.

PH.1. **LAW.**

a. **General.**

1 1917 PULLING, ALEX. (Editor). Manuals of Emergency Legislation: Defence of the Realm Regulations (to June 30th, 1917).

b. **Aeronautical.**

1 1923 SCHLEICHER, Dr. R. Internationales Luftfahrtrecht.
2 1928 U.S. GOVT. PRINTING OFFICE. Civil Aeronautics (Legislative History of the Air Commerce Act of 1926).
3 1929 U.S. DEPT. OF COMMERCE. State Aeronautical Legislation and Compilation of State Laws.
4 1930 WUESTENDOERFER, H. Wege und Ziele des kommenden Weltluftrechts . . . (etc.).
5 1928 GIANNINI, D. Il Diritto Aeronautico. (Magazine.)
(See also PD.2.)

PI.1. **MATHEMATICS.**

1 1910 ALEXANDER, PATRICK. Alexander's Aeronautics. (Tables.)
1a 1912 ELPHINSTONE, G. K. B. The Gyrostatic Compass and Practical Applications of Gyrostats.
2 1913 GRAY, Prof. ANDREW. Gyrostats and Gyrostatic Action.
3 1913 GORDON, J. W. Notes on an Engineering Theory of the Gyroscope.
4 1929 HAHN & WIRTINGER (Editors). Monatshefte für Mathematik & Physik. (Vol. 36, No. 1.)
4a 1932 BOARD OF EDUCATION. Four-Figure Tables and Constants.
5 1935 JACKSON, THOMAS. Slide Rules and how to use them.
6 1937 COMPTON, H. B., and DOHRENWEND, C. O. Solution of the Elastic Curve Equation $M = EI\ (d^2y/dx^2)$.
7 1936 KLEMIN, A., and RUFFNER, B. Operator Solutions in Airplane Dynamics.

PJ.1. **METEOROLOGY.**

a. **Air Ministry and Meteorological Office Publications.**

1 1916 SHAW, Sir NAPIER. The Estimation of Height from Readings of an Altimeter. (M.O.227.)
2 1918 METEOROLOGICAL OFFICE. Meteorological Officers' Reports.
3 1938 CIVIL AIRWORTHINESS COMMITTEE. De-Icing of Aeroplane Wings, Tail Surfaces and Control Surfaces. (A.M. Pamph. 86.)

b. **General.**

1 1908 LEY, Capt. C. H. The Possibility of a Topography of the Air Based on Balloon Observations with Special Theodolites.
2 1911 BUSK, H. G. What will the Weather be?
3 1913 CAVE, CHAS. J. P. The Winds in the Free Air.
4 1927 HOWARTH, O. J. R. Climate and Geography.
5, 6 1929 BOWIE, EDWARD H. Weather and the Airplane. (2 copies.)
7 1931 NATIONAL MET. SERVICE OF CHINA. The Institute of Meteorology: its Organisation and Work.
8 1932 SIMPSON, G. C. Physics in Meteorology.
9, 10 1932 COMMONWEAL PRESS. Questions and Answers in Meteorology. (2 copies.)
11 1933 BOWER, S. MORRIS. Summer Thunderstorms: 3rd Annual Report.
12, 13 1933 MUNRO, R. W. (LTD.). "Dines" Pressure Tube Anemometer, Part I. (2 copies.)
14 1938 MIDDLETON, W. E. KNOWLES (and Others). The Lag Coefficients of some Meteorological Thermometers.

PJ.2. **METEOROLOGY.** (Foreign.)

a. **French.**

1 1906 BRACKE, ALBERT. A la Recherche de Courants d'Air.
2 1925 SCHWEIZERISCHE METEOROLOGISCHE ZENTRALANSTALT. Rapport de la Réunion de la Commission Internationale de Radiation Solaire, à Davos, 31 Août—2 Sept., 1925.
3 1929 COMITE METEOROLOGIQUE INTERNATIONALE. Rapport de la Septième Réunion de la Commission Internationale des Renseignements Synoptiques du Temps (Londres).
4, 5 1935 KAMPE DE FÉRIET, J. La Turbulence de Vent dans les Couches inférieures de l'Atmosphère. (2 copies.)
6 1936 BARLES, JEAN. Découverte d'un second Mouvement de Révolution de la Terre sur elle-même.

b. **German.**

1 1927 ZENTRALANSTALT FUER METEOROLOGIE UND GEODYNAMIK. Bericht über die 12. Versammlung des Int. Meteorologischen Komitees in Wien.
2 1929 HERGESELL, H. Flugwetterdienst und Luftverkehr.

c. **Italian.**

1 1919 EREDIA, FILIPPO. Le Previsioni del Tempo e la Navigazione aerea.

d. **Spanish.**

1 1934 GUARDIOLA, J. M. J. (SERVICIO METEOROLOGICO ESPAÑOL). Notas para una Climatologia de Menorca: Regimen de Vientos.

PJ.3. **METEOROLOGY.** (U.S. Dept. of Agriculture, Weather Bureau.)

1 1914 MARVIN, C. F. Installation and Maintenance of Wind Measuring and Recording Apparatus. (Circular D., Instrument Div.)
2 1929 BLISS, G. S. Weather Forecasting.
3 1930 MARVIN, C. F. Barometers and the Measurement of Atmospheric Pressure.
4 1931 WEATHER BUREAU. Pyrheliometers and Pyrheliometer Measurements.
5 1936 WEIGHTMAN, R. H. Forecasting from Synoptic Weather Charts.
6 1936 McDONALD, W. F. Average Conditions of Wind and Weather. (N. Atlantic Ocean and West Indian Waters.)
7 1937 HURD, W. E. Average Conditions of Wind and Weather. (N. Pacific.)
8 1937 MARVIN, C. F. Psychrometric Tables for Obtaining the Vapour Pressure, Relative Humidity and Temperature of the Dew Point.
9 1938 WEATHER BUREAU. Cloud Forms, according to the International System of Classification.

PK.1. **STRATOSPHERE.**

a. **General.**

1 1935 HILL, Prof. G. T. R. Travel in the Stratosphere.
2-5 1937-39 BRITISH INTERPLANETARY SOCIETY. Journal (Feb., Dec., 1937; Jan., July, 1939).
6 1938 WIMPERIS, H. E. The Boundaries of Flight.

b. **Rocket Propulsion and Special Aircraft.**

1 1930 CHATLEY, HERBERT. The Principles of Rocket Propulsion.
2 1931 STIPA, LUIGI. Aerei per Voli alle alte Quote.

PL.1. **NAVIGATION AND PILOTING.**

a. **Piloting.**

1 1927 LEEMING, J. Pilot's "A" Licence. (Original Ed.)
2 1927 FRICKE, HERMANN. Vom Fliegen und Fliegenlernen.
3 1929 GUGGENHEIM FUND. Solving the Problem of Fog Flying.
4 1938 BROWNE, C. G. K. "A" Licence Technical.

b. **Navigation.**

1 1908 RAMBALDO, A. E. Astronomische Ortsbestimmung im Ballon.
2 1916 WHITE, JAMES D. Steering by the Stars.
3 1922 COUTINHO, G., and CABRAL, S. Aerial Navigation. (Text in Portuguese, English, French and German.)
4 1939 AQUINO, R. DE. Isoazimuthal Lines of Position at Sea and in the Air.

PL.2. **AERIAL PHOTOGRAPHY AND SURVEY.**

1 1920 THE AIR BOARD, CANADA. Report on Experimental Aerial Survey at Ottawa, 1920.
2 1922 AIR MINISTRY. Universal Camera Mounting. (A.P.913.)
3 1924 LOGAN, R. A. Some Commercial Uses of Aerial Photographic Surveying.
4 1928 DEPT. OF THE INTERIOR, CANADA. A Graphical Method of Plotting Oblique Aerial Photographs.
5 1930 ———— Preliminary Report on the Aerial Mineral Exploration of Northern Canada.
6 1937 BROWN, Major R. LL. Revision of Ordnance Survey 25-inch Plans from Air Photographs.
7 1930 S.A.B.E.P.A. Aérographie.

PL.3. **AVIATION MEDICINE.**

1-3 1922 AIR MINISTRY. Medical Notes in connection with Commercial Aircraft. (3 copies.)
3a 1930 GIACOMELLI, Dr. R. Una Questione di Nomenclatura in Medicina Aeronautica.
4 1931 WILSON, Major G. The Army Medical Service in War.
5 1934 AIR MINISTRY. Medical Notes and First-Aid Treatment for Flights in the Tropics and Sub-Tropics.
6 1935 SECRETARY OF STATE FOR FOREIGN AFFAIRS. International Sanitary Convention for Aerial Navigation, The Hague, 12th April, 1933.
7 1938 MACKIE, F. P., and CRABTREE, H. S. The Destruction of Mosquitoes in Aircraft.
8 1938 MINISTER OF HEALTH. Public Health, England, Aircraft Regulations, 1938. (S.R. & O., 1938, No. 299.)
9 1938 ———— Circular accompanying above Order (No. 1677).

PL.4. **MAPS.**

a. **Route Maps.**

1 TRANS-EUROPA-UNION. Genf-Zürich.

2 ——— Zürich-München.

3 ——— München-Wien.

4 ——— Wien-Budapest.

5 ——— Fürth-Frankfurt-am-Main.

6, 7 ——— München-Fürth. (2 copies.)

8 NORD-EUROPA-UNION. Königsberg-Memel-Riga.

9 JUNKERS LUFTVERKEHR & SAECHSISCHE LUFTVERKEHR. Berlin-Dresden.

10 DEUTSCHE LUFTHANSA. Berlin-Braunschweig-Dortmund-Essen-Düsseldorf-Cöln: Berlin-Magdeburg-Cöln.

11 P.L.L. AEROLLOYD. Warschau-Lemberg.

12 ——— Danzig-Warschau.

13 KONINKLIJKE LUCHTVAART MAATSCHAPPIJ. Amsterdam-Hamburg.

14 ——— Amsterdam-London.

b. **General.**

1 1897 Russian Railways.

2 1900 German Balloon Flights.

3 1907 Ordnance Survey Aero Map, Sheet 15 (Midlands).

4 ?1937 Madrid and Environs.

PM.1. **ELECTRICITY.**

a. **Magnetism and Electricity.**

1 1919 LAMB, C. G. Notes on Magnetism for the Use of Students of Electrical Engineering.

2 1927 METEOROLOGICAL OFFICE. Commissions for Terrestrial Magnetism and Atmospheric Electricity and for the Réseau Mondial. (Zurich Meetings, 1926.)

3 1934 I° CONGRESSO INT. DI ELETTRO-RADIO-BIOLOGIA. Programma Preliminare. 10-14 Sept., 1934—Venezia.)

b. **Aircraft and Ground Lighting.**

1 1926 CALLOU, L. La Recherche des Avions au Moyen de Projecteurs.

PM.2. **WIRELESS.**

a. **General.**

1 1919 BRIGHT, Sir CHARLES. Inter-Imperial Communication through Cable, Wireless and Air.

2 1924 DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Variations of Apparent Bearings of Radio Transmitting Stations (Part I).

3 1933 APPLETON, Prof. E. V. Empire Communications.

b. **Aeronautical Radio and Direction-Finding.**

1 1925 AIR MINISTRY. The Elimination of Interference from Radio-Receiving Apparatus. (A.P.1136.)

2 1930 GUGGENHEIM FUND. Equipment used in Experiments to Solve the Problem of Fog Flying.

3 1931 KEAR, F. G., and WINTERMUTE, G. H. A Simultaneous Radiotelephone and Visual Range Beacon for the Airways.

4 1931 HINMAN, W. S. Automatic Volume Control for Aircraft Radio Receivers.

5 1931 DUNMORE, F. W. A Course Indicator of Pointer Type for the Visual Radio Range-Beacon System.

6 1934 AIR MINISTRY. Orfordness Rotating Wireless Beacon.

7, 8 1939 ——— V.H.F. Radio-beacon Landing-Approach Installations.

c. **Radio Code and Morse Code.**

1 1922 AIR MINISTRY. The Wireless Weather Manual. (M.O.255.)

2, 3 1938 U.S. DEPT. OF AGRICULTURE. International Code for Radio Weather Reports from Ships. (2 copies.)

4 1939 GENERAL POST OFFICE. Handbook for Wireless Operators.

5 1940 BROWN, SON & FERGUSON (Publishers). Brown's "Vick" Morse Cards.

PN.1. **SCIENCE AND PHYSICS.**

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5 1931 RYNIN, N. A. The Most Profitable Length of Airline Stage. *(In Russian.)*

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9 1933 MILES, G. H. M. Notes on the Operation and Maintenance of Commercial Aircraft.

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Oct. Seven Flying Safety Factors. (Imperial Airways "Hannibal" Class.)
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Aug. Civil Aviation in South Africa. (Sir Abe Bailey's Munificent Gift.)
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3 1925 HARRIS, R. G., and CAYGILL, L. E. Experiments on Steam Radiators. (Royal Aircraft Establishment Report No. B.A.539.)

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6 1935 SHOEMAKER, J. M., RHINES, T. B., and SARGENT, H. H. Further Progress in Controlled Cooling of Radial Aircraft Engines.

7 1935 OTTEN, G. A View on the Thurston Rotor Cowl for Air-Cooled Engines.

7a 1937 WALLS, FRED J. Cast Camshafts and Crankshafts Possess Many Advantages.

8 1939 JOURNAL DE LA MARINE MARCHANDE. L'Evolution des Moteurs d'Avions.

9 1939 AERONAUTICAL CHAMBER OF COMMERCE OF AMERICA, INC. Aero Engine Production in the U.S.A.

10 FEDDEN, A. H. R. Development of the Mono-Sleeve Valve for Aero Engines. 1938. (Bi-Lingual: English/German.)

Section b. Oil Engines and Turbines.

1, 1a 1931 CHORLTON, ALAN E. L. Development of the High-Speed Oil Engine in England (with photo of R.101 engine.) (2 copies.)

2 1936 INSTITUTE OF MARINE ENGINEERS. The Care and Maintenance of a Modern Diesel-Engined Tanker Fleet.

3 1936 ———————— Notes on the Turbo-Electric Propulsion Equipment of the Liner "Normandie."

3a 1936 GASTERSTAEDT, Dr. J. Junkers Flug-Dieselmotor.

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2 1926 DUNSTAN, A. E. Fluid Fuels.

3 1928 TRAVERS, MORRIS W. Experimental Investigations on the Heat of Formation of Liquid Water and of Carbon Dioxide.

4 1928 ———————— The Chemical Study of Processes Involving the Carbonisation of Coal by Internal Heating.

5 1928 TEGNER, H. S. The History and Development of Anti-Detonating Agents for Motor Fuel.

6 1928 ———————— (2nd copy.)

7 1932 ETHYL EXPORT CORPN. The Fuel Problems of the 1931 Schneider Trophy Contest and the World's Record Attempt.

8 1934 PONTREMOLI, JEAN. La Détonation et quelques Problèmes qu'elle pose, vus par le Constructeur de Moteurs.

9 1939 COLLOIDAL PRODUCTS. A New Notion of Running-in.

10 1939 PELETIER, L. A., and HOOGSTRATEN, S. G. VAN. Rating High Octane Fuels.

11 1938 KUHRING, M. S. Water and Water-Alcohol Injection in a Supercharged Jaguar Aircraft Engine. Cooled Armstrong-Siddeley Leopard Engine.

12 1940 *IMPERIAL REVIEW (March). The Problem of Petrol and Oil Supplies.*

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1928 ARMSTRONG SIDDELEY. The Jaguar Reduction Gear.

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?1926 ———————— The Bristol Jupiter Air-Cooled Aero Engine (Series VI) and its Production.

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1937 ———————— The Production of Bristol Pegasus and Mercury Engines. (Reprint from "Machinery.")

? ———————— The First Fully Supercharged Sleeve-Valve Aero Engine. (Perseus X.)

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Sept. 1935 *British Engines in American Air Liners. (Pegasus III.)*

Nov. 1935 *Sleeve-Valve Engines for Aircraft: Success of the Bristol "Perseus."*

April 1936 *Engines for Empire Flying Boats (Pegasus X).*

Oct. 1936 *Sleeve-Valve Aero Engines: Successful Service. Tests.*

Jan. 1938 *Power of the Bristol Hercules Aero Engine.*
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Nov. 1938 *A Magnificent Feat: Bristol Engines and World Record. (Pegasus XXII.)*
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——— Gipsy Engine Successes, 1933.
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1940 "FLIGHT" 18.1.40). The Junkers Petrol Injection Engine (Jumo 211A).
1938 JUNKERS - FLUGZEUGWERKE. Development of Junkers High-Power Aero Engine Jumo 210.
? ——— Junkers Benzin Flugmotor Jumo 210.
1924 RENAULT. Les Moteurs d'Aviation Renault : Historique de leur Fabrication, 1907-1924.
? ——— Moteur d'Aviation Renault : 480 C.V.
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1926 J. WALTER & Co., Prague. Performances et Succès des Moteurs Walter.
1926 ——— Les Dernières Victoires du Moteur Walter 60 C.V.
? ——— Moteurs d'Aviation "Walter 85."
1939 *WRIGHT AERONAUTICAL CORPN. Vers le Moteur de 3.000 CV. (From "Journal de le Marine Marchande," 2/3/39.)*

Y.8. **ENGINEERING.**

Section a. General.

1 1926 DEUTSCHE VERSUCHSANSTALT FUER LUFTFAHRT. Ueber die Lastannahmen bei der Festigkeitsrechnung von Flugzeugen.
1a, 2 1927 KAHN, L. L. Les Bordés travaillants en construction Navale et Aéronautique. (2 copies.)
2a 1930 PANETTI, Modesto. Notizie Generali sulle Oscillazioni dei Veicoli.
3, 4 1932 KIRSTE, Leon. Flexion et Torsion des Ailes Cantiléver. (2 copies.)
5 1933 HOWARD, Major C. W. Progress in Aeronautical Engineering.
5a 1933 KONDO, Masaiti. Bouncing and Shock Load of an Aeroplane in Landing.
6 1934 COX, H. Roxbee. On the Synthesis and Analysis of Simply Stiff Frameworks.
7 1935 MARSHALL, C. F. Dendy. The Germs and Development of Some Mechanical Inventions.
8 1936 CHITTY, L., and PIPPARD, A. J. S. On an Experimental Method for the Solution of Plane Stress Problems.
9 1939 *IMPERIAL REVIEW (May). Detecting Fractures. (Met.-Vickers Detector.)*
10 1936 WORLD POWER CONFERENCE. Programme (Washington Meeting.)
11 1938 ——— Technical Programme. (Vienna Sectional Meeting.)
12 1939 KEINZLE, O. Up-to-date Machine Tools.
13, 14 1939 PRITCHARD, J. L. Aeronautical Engineering and Aircraft Manufacture. (2 copies.)

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1 1919 BROWN & BARLOW, Ltd. The B. & B. Flowmeters and Jet Calibrating Machines.
2 1937 COLEBROOK & WHITE. The Reduction of Carrying Capacity of Pipes with Age.
3 1938 WALLIS, R. P., and WHITE, C. M. Resistance to Flow through Nests of Tubes.
4 1939 WALLIS, R. Pendennis. The Optimum Size of Models for Studying Flow through Nests of Tubes.

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1 1932 AIR MINISTRY. A.M. Pamphlet 34 (5th Ed.): Instructions to Applicants for G.E.'s Licences and Syllabus of Examinations.
2 1934 U.S. DEPT. OF COMMERCE. Memorandum to Aircraft Owners, Operators and Pilots. (Information concerning Aircraft Maintenance.)

3 ? AERO ENGINEERING & ADVISORY SERVICE, INC. News Letter to Engineers.

4 ? U.S. DEPT. OF COMMERCE. Air Commerce Manual No. 18. Repair and Alteration of Aircraft.

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Y.9. GENERAL INFORMATION.

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DEUTSCHE LUFT HANSA. Le Développement des Services Aériens de la Deutsche Lufthansa dans le monde. (Journal de la Marine Marchande: 2/3/39.)

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SEAPLANES. The Experimental Development of Anchors for Seaplanes. By Wing-Com. D. F. Lucking. (Inst. of Naval Architects, Paper No. 11, 1936.)

SCHOOLS. L'Aéronautique et l'École. (Reprint from "La Technique Moderne," Vol. 28, No. 22 (15.11.36).

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YANKEE CLIPPER. An Overnight Flight in the Yankee Clipper. (Personal letter to friends by Lester Gardner; undated—abt. 1937/38.)

Y.10. GLIDING AND SOARING, BIRD FLIGHT, MODELS.

Section a. Gliders and Gliding, Ornithopters.

1 1898 ADAMS, ALEXANDER. Mechanical Flight on Beating Wings: The Solution of the Problem.

2 1912 LILIENBACH, CARL LILL v. Motorflug und Segelflug.

3 1922 *THE TIMES. Gliding Competition in Germany (Wasserkuppe),* 21/8/22.

4 1934 TROMMER-MICHAEL. Rhön-Bussard, Rhön-Adler 32. (Prospectus.)

5 1928 GIACOMELLI, R. Les Machines volantes de Léonard de Vinci et le Vol à Voile.

6 1935 SLATER, Dr. A. Gliding. (Typescript of Lecture.)

7 1937 BUXTON, Sqd. Ldr. G. M. Development of Sailplanes.

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1 1914 HANKIN, Dr. E. H., and WATSON, D. On the Flight of Pterodactyls. (Reprint from R.Ae.S. Journal, Oct., 1914.)

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2 1915 HANKIN, Dr. E. H. On the Flight of Albatrosses and Gannets. (Reprint from R.Ae.S. Journal, Jan., 1915.)
3 1917 ———————— Soaring Flight. (Lecture delivered before Indian Science Congress, Bangalore, 11.1.17.)
4 1920 DE VILLAMIL, Lt.-Col. R. Soaring Flight : A Simple Mechanical Solution of the Problem.
5 1937 *ILLUSTRATED LONDON NEWS. A Flying-Lesson from the Bat: High-Speed Photographs.*

Section c. Soaring (Theory).

1 1903 BERTELLI, A. Ricerche d'Aeronautica.
2 1909 CHANUTE, Octave. Soaring Flight.

Section d. Model Aircraft.

(See also Y.3.i.G for early types.)

1 1929 URSINUS, Oskar. Flug-Modell-bau-Unterricht.
2 ?1909 Pictures of Very Early Flying Models. (Unidentified source.)
3 1940-41 STEVENS, James H. Scale Model Aircraft (Series). No. 7 (Heinkel HE.113); No. 8 (Lockheed P.38); No. 9 (Breda 88 Fighter-Bomber).

Y.11.i. HISTORICAL. (Up to 1903.)

Section a. Pamphlets, etc.

1 1848 ———————— Flying Machines. (Article in Chambers's Edinburgh Journal, 6.5.48 : Commentary on "Aerial Navigation" by Doedalus Britannicus.)
2 1885 LACROIX, Désiré. Les Aérostiers Militaires du Château de Meudon (1794-1884).
3 1889 YON, G., and SURCOUF, E. Aérostats et Aérostation Militaire.
4 1891 MAXIM, Sir Hiram. Aerial Navigation : the Power Required. Article in "The Century Illustrated Monthly Magazine," Oct., 1891.)
5 1892 FULLERTON, Capt. J. D. Modern Aerial Navigation. (Galley proof of Lecture to Royal United Services Inst.)
6, 6a 1893 ———————— Phillips' Flying Machine. (Reprint from "Engineering," March 10, May 5 and 19, 1893.) (2 copies.)
7 1893 JAROLIMEK, A. Ueber das Problem dynamischer Flugmaschinen. (Reprint from Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines.)
8, 9 1894 MAXIM, Hiram S. Experiments in Aeronautics. (Paper read 28th Nov., 1894, before Society of Arts. Reprint in Journal, Nov. 30, 1894.) (2 copies.)
10 1897 KOCH, Gustav. The Paddle Wheel Flying Machine. (Mimeographed.)
11 1898 ADAMS, Alexander. Mechanical Flight on Beating Wings. The Solution of the Problem.
12 1898 DAVIDSON, George L. O. The Flying Machine of the Future. (Galley Proof of Lecture.)
13 ? CHADDOCK, George A. Mechanical Air-Borne Ship. (Specification.)
14 1900 CHANUTE, Octave. Aerial Navigation. (From "The Independent.")
15, 16 1901 ———————— Experiments in Flying : Aerial Navigation. (Two articles stapled together, the latter from "Cassier's Magazine.")
17 1901 AMERICAN INST. OF ELECTRICAL ENGINEERS. Notes on the Aerodrome of Mr. Langley.
18 1903 HEDELBERT, S. Gare de Dirigeables : Projet de M. H. J. Glaizot. (Article in "Revue Générale des Transports.")
19 1903 BERTELLI, A. Ricerche d' Areonautica (sic).
20 1903 CAPONE, Federico. Etude sur le Vol.
21 1903 RENARD, Charles. Sur la possibilité de soutenir en l'air un Appareil volant du genre hélicoptère en employant les moteurs à explosion dans leur état actuel de légèreté.
22 ? BACON, Rev. J. M. (and Others). Aerial Research. (Syllabus of Experimental Work in connection with a Series of Scientific Balloon Ascents.)
23 ? MAHAN, F. M. Mahan's Aerial Navigator.

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1 1883 *BRAYTON PETROLEUM ENGINE CO. Prospectus of Petroleum Engine.*
2, 3 1893 *"THE TIMES," 24/5/93. Phillips' Aerial Machine.* (2 reprints.)
4 1901 *"BLACK & WHITE," 7/12/01. Shall We Ever Fly? By Sir Hiram Maxim.*

(*Cuttings from "THE ILLUSTRATED SCIENTIFIC NEWS."*)

5 1902 (*Oct.*) *A New Method of Inflating Balloons.*
6 1902 (*Oct.*) *Aeronautics at Bath.*
7 1902 (*Oct.*) *Review of F. Walker's "Aerial Navigation."*
8 1902 (*Nov.*) *Notes on contents of "Aeronautical Journal" for Oct. 1902.*
9 1902 (*Nov.*) *The de Bradsky Navigable Balloon.*
10 1902 (*Nov.*) *Sounding the Atmosphere with Kites.*
11 1903 (*Jan.*) *Review of Bacon's "The Dominion of Air."*
12 1903 (*Feb.*) *By O. Chanute. Gliding Machines.*
13 1903 (*Mar.*) *Sounding the Upper Air. (Results of ascents arranged by International Commission, Dec. 4th.)*

14 1903 (*May*) *Review of Lecornu's "La Navigation Aérienne."*
15 1903 (*Nov.*) *Patent No.* 11,982. *Flying Machines.* (*J. Seiberl.*)
16 1903 (*Dec.*) *Result of Prize Competition ("A Flying Machine").*
17 ? (*Unidentified source*). *Mechanical Flight up-to-date. By Sidney H. Hollands. Chapter IX, conclusion.*

Y.11.ii. **HISTORICAL (1904 to 1913).**

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1 1904 BOURCART, Max. Particulars of the Flying Machine Invented by Max Bourcart of Colmar (Alsace).
2 1904 DELPRAT, André. Flying Machines with Paddling Wings having a Continuous Effect without Balloons, Screw-Propellers or Aeroplanes.
3 1904 RENARD, C. Sur un nouvel appareil destiné à la Mesure de la Puissance des Moteurs.
4 1904 CHANUTE, Octave. Aerial Navigation.
5 1905 SANTOS-DUMONT, A. The Sensations and Emotions of Aerial Navigation.
6 1905 VIVES Y VICH, Don Pedro. El Real Aéreo-Club de España.
7 1906 LILIENBACH, Carl Lill von. Vorbereitung zum Fliegen.
8 1908 WEISS, José. The Problem of Flight.
9 1908 BRUCE, Eric Stuart. Mechanical Flight.
10 ?1908 (?) MAXIM, Sir H. The Conquest of the Air. (Incomplete magazine article.)
11 1909 COMMONWEALTH OF AUSTRALIA. Flying Machines for Military Purposes. (Competition.) Conditions.
12 1909 GRAHAME-WHITE, C. Prospectus of Aeroplanes for Sale. (Photostat.)
13 1909 MARCUSE, Dr. Adolf. Navigation in der Luft.
14 1909 SIMMS MANUFACTURING Co. Ltd. Simms 50 h.p. Aero-Motor. (Blueprint.)
15 1909 GOBRON-BRILLIE. The "Gobron" Aeronautical Engine. (Catalogue.)
16 1909 HOFMANN, J. Die Berliner Flugwoche und einige ihrer Lehren.
17 ?1909 MAXIM, Sir Hiram S. The Evolution of the Aeroplane Flying Machine.
18 ? GREEN'S MOTOR PATENTS. Green's Motor for Aerial Navigation.
19 1909 CHATLEY, Herbert. Difficulties in the Construction of Aeroplanes.
20-22 1910 TURNER, Charles C. Cantor lectures on Aeronautics. (2 copies Collective Ed., 1 copy Lecture 2 only.)
23 1910 HELE-SHAW, Dr. H. S. A Comparison of the Problems Presented Respectively by the Dirigible and the Aeroplane.
24 1910 ENGINEERING WONDERS OF THE WORLD. Part 15 (Special Aeronautical Number).
25 1910 ENCYCLOPÆDIA OF SPORT. Part I. Article: "Aeronautics."
26 1910 LIBRAIRIE AERONAUTIQUE. Lectures Aéronautiques: No. 4. (15.8.10.)
27, 28 1911 MAXIM, H., and HAMMER, W. J. Chronology of Aviation. (2 copies.)
29, 30 1911 AERIAL LEAGUE OF THE BRITISH EMPIRE. Alexander Prize Competition for Aerial Motors. Entry Form. (2 copies.)
31 1911 ADVISORY COMMITTEE FOR AERONAUTICS. Report on the Results of the Petrol Motor Trials in the Competition for the Alexander Prize.
32 1911 AERIAL LEAGUE OF THE BRITISH EMPIRE. Alexander Prize Competition for Aerial Motors. Regulations and Conditions of Test.
33 ? E.N.V. MOTORS, Ltd. Aviation. (Catalogue.)
34 1911 TARIDE, A. (Publisher). L'Aviation et les Aviateurs par l'Image.
35 1912 GILLINGHAM, James. A Tribute to John Stringfellow of Chard.
36 1912 HARMSWORTH'S POPULAR SCIENCE. The Flight of Man. (12.3.12.)
37 1913 DAIMLER - MOTOREN - GES. Neues vom Mercedes Flugmotor.
38 1913 WM. COWARD & Co. Ltd. Commemorative Souvenir: 1837-1913. (Describes Hamel's Plane "Britannia.")

Section b. Newspaper Cuttings. (See also ENVELOPE FILES.)

1 *WRIGHT AEROPLANE.* (*Aug.* 10 *and Sept.* 10, 1908.) *DAILY MAIL.*
2 *Holiday on a Hydroplane. DAILY MAIL. Sept.* 10, 1908. (*Hydroplane = speed boat, NOT Seaplane.*)
3 *Flying: the Sport and Travel of the Near Future. By H. Hewitt Griffin. T.P.'s WEEKLY,* 5/3/09.
4 *Flying: Aero Club Exhibition and Motor Boat Exhibition, Olympia. March* 19-27, 1909. *Description of Models at Mr. Shapland's Stand.*
5 *PAULHAN: Altitude Record* (977 *feet*). *Nov.* 8, 1909. *DAILY SKETCH.*
6 *How Aviation is Advancing.* (*Unidentified Newspaper Supplement: about March* 1911.)
7 *Waterplanes.* ("*Daily Mail*" *Exhibition flights at the seaside.*) *DAILY MAIL,* 2/7/12.
8 *Dublin-Belfast Race: Sept.* 9, 1912. *DAILY SKETCH.*
9 *HAMILTON AND WYNESS STUART. Fatal accident in Army Monoplane: Sept.* 7, 1912.
10 *CODY, Colonel. Accident at Doncaster* (16/10/09); *Fatal Accident* (*Aug.* 1913).

Y.11.iii. **HISTORICAL (1914 to 1918).**

Section a. The Great War.

1 1914 "TIMES" HISTORY OF THE WAR. Article: Military Aeronautics and the British Air Service. (Part 18. Dec. 22nd, 1914).

2 1916 ———————— Article: German Air Raids, Feb.-May, 1916. (Part 96.)

3 1917-18 THE AIR BOARD. Envelope Containing Confidential Information Memoranda Nos. 38, 48, 50, 55, 59, 61.

4 1918 LEHMANN, Dr. Fleigerrettung aus Seenot. (Typewritten MS.)

Section b. General.

1 1916 WHITEHEAD AIRCRAFT Co. LTD. Extension of the Works: Opening Ceremony, 10.7.16.

2 1918 MINISTRY OF MUNITIONS (PIPPARD and PRITCHARD). H.B.806: Handbook of Strength Calculations. (Original Ed., with Mr. Pritchard's MS. amendments.)

Y.11.iv. **HISTORICAL (From 1919).**

Section a. Pamphlets, etc.

1 1920 "NASHA STIKHIA" (Our Sphere). Russian Magazine, containing article on Aviation in the Civil War. (Rough notes of contents made in English.)

2 1926 (COBHAM, Sir ALAN.) Programme of Luncheon at Connaught Rooms, 4.10.26 (giving description of flights).

3 1928 (————————) Banquet by R.Ae.S., Royal Aero Club, etc., 8.6.28.

5 1928 MARSH, Lt.-Col. W. LOCKWOOD. Flying.

6 1928 GIACOMELLI, R. Les Machines volantes de Léonard de Vinci et le Vol à Voile.

7 1928 LETECTVI (Czech Magazine). Le Mois Aéronautique Tchécoslovaque. (1918-28.)

8 1929 INTERNATIONAL AERO EXHIBITION. Twenty-Five Years of Flying.

9 1929 "THE AEROPLANE" (16.1.39). Articles on R.A.F. Far East Flight.

10 1930 BLACKBURN AIRCRAFT. The Blackburn Aeroplane & Motor Co. Ltd.

11 1930 GIACOMELLI, R. Lo Studio Aerologico del Vento in Leonardo da Vinci.

12 1931 BLACKBURN AIRCRAFT. A Brief History of the Blackburn Aeroplane & Motor Co. Ltd. (1909-31) and North Sea Aerial & General Transport Ltd. (1919-31).

13 1931 GIACOMELLI, R. I Modelli delle Macchine Volanti di Leonardo da Vinci.

13a 1933 DE HAVILLAND AIRCRAFT CO. Gipsy Engine Successes, 1933.

14 1934 OBRUTSCHEW, Prof. S. Die Erforschung des Tschuktschen-Gebietes vom Flugzeug, 1933. (Reprint from Petermanns Geographischen Mitteilungen.)

15 1936 GULF OIL CORPORATION OF PENNSYLVANIA. Aviation Atlas, 1935.36.

16 1937 SHACKLETON, W. S. Random Notes on a Visit to the U.S.A. and Australasia.

17 1937 BRISTOL AEROPLANE Co. 53,937 feet (Flt.-Lt. Adam's Altitude Record).

18 1938 FAIREY, C. R. In the Early Days of Flying.

19 1939 WIMPERIS, H. E. The Future of Flying.

20 1937 L'AVIATION BELGE (Magazine). Almanach 1938 de l'Aviation Belge.

*21 1940 HANLON, MARC. Rebuke to Science. (Pénaud-Gauchot Airplane Patent, 1876.)

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1 1935 *CAYLEY, Sir George. Discovery of unknown Cayley Engraving.* (*TIMES*, 19/6/35.)

1a 1935 *ROE, Sir Alliott V. A Quarter of a Century of Aviation.* (*THE IMPERIAL REVIEW: May* 1935.)

2 1938 ———————— *The Airship K.1. The Airship J.4.* (*Typewritten data:* 20/5/38.)

3 1939 *FINANCIAL TIMES. Supplement "Italy and her Empire,"* 12/1/39. *Article: "Speed—Distance—Height: Aviation Industry's notable Achievements."*

4 1939 *SUNDAY EXPRESS,* 23/7/39. *"They said the Atlantic would never be flown." Article by C. A. Lyon.*

5 1939 *SHEERNESS TIMES AND GUARDIAN,* 24/11/39. *"Early Flying Days at Eastchurch." Article by W. C. Sutton.*

Y.12. **INSURANCE AND MEDICAL.**

Section a. Safety, Accidents, Insurance.

1 1921 ROYAL AERONAUTICAL SOCIETY: London-Paris Service.

2 1928 PRESSMAN, MILDRED B. Bibliography for the Insurance Underwriter.

3 1930 *BARBER & BALDWIN ENGINEERING SERVICE. News Letter to Engineers, Oct.* 1930. *Fire Losses, etc.*

4 1931 LEDERER, JEROME. Some Design Factors which Influence Aviation Insurance Rates.

5 1935 *IMPERIAL REVIEW. You are safer flying in British Machines.* (*Accident statistics,* 1927-32.)

6 1932 AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Inspection Manual for Maintenance of Conventional Aircraft. (Tentative Draft.)

7 1935/9 *AERO INSURANCE UNDERWRITERS. News Letters from Engineering Department. Nos.* 42, 63, 64, 68, 69.

8 1937 JUNKERS-FLUGZEUGWERKE. Sicherheit durch Junkers-Bauweise. (*Interleaved German and English.*)

9 ? ——————— Difficult Night Mail Flight of a Junkers Ju.52/3mW from Rio de Janeiro to Bahia.

10 LEDERER, JEROME. The Safety of the Airlines of the United States compared with those of the rest of the World.

11 1939 ——————— Vanity versus Gravity.

12 1939 ——————— Loss Prevention in Non-Scheduled Civil Aviation.

Section b. Medical.

1 1923 BRICHAMBAUT, Dr. P. DE, and BEHAGUE, P. Malaises des Aviateurs.

1a 1931 RYNIN, N. A., & LIHAGHEV, A. A. Effect of Accelerations on Living Organisms. (*In Russian with English résumé.*)

2 1936 FEDERATED COUNCIL OF AUSTRALIAN AERIAL MEDICAL SERVICES. Aerial Medical Services (and other pamphlets).

3 1936 *IMPERIAL REVIEW* (*Dec.*). *The Flying Doctors of Australia.*

4 1936 LEAGUE OF RED CROSS SOCIETIES. Summary of Minutes of a Meeting of the International Committee for the Study of Air Ambulance Problems (Jan. 17th, 1936).

5 1937 LIGUE DES SOCIETIES DE LA CROIX ROUGE. Comptes rendus de la Conférence Technique Internationale des Secours Aériens (Budapest, 11-14 Juin 1937).

(*Nos.* 6-15 *are papers read at the above Meeting.*)

6 1937 FIUMEL, Lt.-Col. ANTONIO. The Organisation of Air Ambulance Services in Poland.

7 1937 SLOTBOOM, K. M. Carrying Patients by Aeroplane.

8 1937 STJERNSTEDT, Baron. Methods of Collaboration between Aeronautical Associations and the Red Cross for Aerial Relief.

9 1937 SCHICKELE, Surgeon-General. The Transformation of Private and Commercial Aeroplanes for Air Ambulance Purposes.

10 BEHAGUE, Dr. PIERRE. Private Aviation and Aerial Relief.

11 1937 FERRONI, Col. ARMANDO. Revictualling from the Air.

12 1937 SECRETARIAT OF THE CONGRESS. Parachute for Dropping Packages of Food and Medical Supplies.

13 1937 MERENY, Dr. GUSTAVE SCHOLTZ DE. Hungary's Attitude to the Air Ambulance Problem.

14 1937 DENOIS, E. The Rôle of the Parachute.

15 1937 COWELL, Col. E. M. Air Medical Transport in Gt. Britain.

16 1938 MINISTRY OF HEALTH. Safeguarding Health at the Airports. (Note on the Public Health (Aircraft) Regulations, 1938.)

17 1938 *IMPERIAL REVIEW* (*Dec.*). *Eliminating the Insect Pest from Air Liners.*

18 1940 *MARSHALL, G. Struan. Physiological Problems of Human Flight.*

19 1940 "*THE ENGINEER,*" 23/2/40. *High Altitude Flying.*

Y.13. **MATERIALS.**

Section a. General Information.

1 1927 LESTER, H. H. The X-Ray Testing of Metals at Watertown Arsenal.

2 1929 W.G.L. JAHRBUCH, 1929. (Extract : Three Articles by Bollenrath, Hilbes and Mathar on Light Metal Alloys.)

3 1931 WARNER, DAVID M. Special Methods of Testing Aircraft Materials.

4 1932 HOUNSFIELD, L. H. A New Method for Measuring the Mechanical Properties of Metals.

5 1933 "AVIATION INDUSTRY." (Russian Magazine : Articles on Corrosion and Technology of Metals.) *In Russian.*

6 1933 MINISTERE DE L'AIR. Norme Air 0754.

7 1934 BOLLENRATH, F. Ein neues optisches Dilatometer.

8 1937 THEODORIDES, PH. X-Ray Study of a New Aviation Alloy in connection with Mechanical Stressing.

9 1937 *IMPERIAL REVIEW. The Story of Hadfield's Ltd.*

10 1937 HAGGENMILLER, H. Modern Methods of Sheet Metal Working in Metal Aircraft Construction.

11 1939 ARMOUR INSTITUTE OF TECHNOLOGY, U.S.A. Research Foundation Foundry Building. (Laying of Foundation Stone.)

12 1939 "LA TREMPE" (Magazine). Les Aciers spéciaux dans la Construction Aéronautique Britannique.

Section b. Welding.

1 1934 BOLLENRATH, FRANZ. Behinderte Formänderung in Schweissnähten.

2 1936 BARRELON, IVAN N. La Soudure électrique des métaux légers par points et à la molette, et son application dans la construction aéronautique.

3 1937 PLEINES, Dr. WM. Die Nietung im Leichtmetall - Flugzeugbau.

4, 5 1940 FIELD, G. H., and SUTTON, H. Investigations on the Spot Welding of Light Alloys. (2 copies.)

Section c. Specific Materials.

Aluminium and Its Alloys.

1930 BRITISH ALUMINIUM Co. LTD. International Competition for the Development of the Uses of Aluminium and its Alloys. (Rules.)

? ———— Aluminium Paint in Industry.

1939 LIGHT METALS (Magazine). Light Metals in American Aircraft Design.

1939 HIGH DUTY ALLOYS (W. G. Devereux). Aluminium Alloys in Aircraft.

1940 LIGHT METALS (March). Aircraft Fuel Tanks in Aluminium Alloys.

1940 ———— Light Alloys in American Aircraft Engines.

1940 HOUGHTON, P. S. Aircraft Component in Aluminium Sheet.

1940 ———— Production of Aircraft Component in Alclad.

Duralumin.

(1930) Der Flugzeugbaustoff — Duralumin. By H. Lennartz.

Inconel.

1939 HENRY WIGGIN & Co. LTD. Inconel: an Account of its Properties, Typical Uses and Fabrication.

Iron.

1936 IRON & STEEL INSTITUTE. Committee of Representatives of Technical Institutions and Societies on Testing and Materials: First Meeting, 30.1.36.

Monel.

1939 HENRY WIGGIN & Co. LTD. Monel: an Account of its Properties, Typical Uses and Fabrication.

Plastics.

1940 "PLASTICS" (Magazine) (Feb.). Cellulose Acetate in Aircraft Manufacture. (Also 2 copies reprint.)

1940 ———— The Timm Trainer. (All-Plastic Aircraft.)

1939 O. LEUMANN. Machines for Thermo-Plastic Materials and for Die-Making.

1937 LANGLEY, MARCUS. Plastics in Aircraft Construction. (Articles 1 and 3.)

1940 POTTER, H. V. Plastics as Constructional and Engineering Material.

? ———— Tables giving Properties of Plastics.

1940 PERRY, H. WILKIN. Plastic Aeroplanes in Production.

Steel.

1917 LERICI, C. M. Sulla Misura della Tensione dei Fili e Cavi di Acciaio col Metodo delle Vibrazioni applicato alle Costruzioni Aereonautiche.

1935 HATFIELD, Dr. W. H. The Heterogeneity of Steel Ingots. (2 copies.)

1936 *IMPERIAL REVIEW (Aug.). How Weight Saving vitally concerns Engineering Construction. (Re: Ducol Steel.)*

1937 ———— *(April). Structural Steel in Factory Construction.*

1937 ———— *(Sept.). A Weight-Saving Steel: the many Advantages of "Ducol."*

Timber.

(See *W: Wood.*)

Wood.

1939 DEPT. OF SCIENTIFIC & INDUSTRIAL RESEARCH. Forest Products Special Report No. 5: "The Growth, Structure and Properties of Wood." (Summary.)

1940 ———— Timber Research: Progress at the Forest Products Research Laboratory.

Y.14. METEOROLOGY.

Section a. Meteorology.

Articles from ILLUSTRATED SCIENTIFIC NEWS.

Dec. 1902 *London Fog.*

Aug. 1903 *A New Method for Making Weather Forecasts.*

Dec. 1903 *Lightning Flashes and their Spectra. By Dr. W. J. S. Lockyer.*

Jan. 1904 *Weather Forecasts and the Barometer.*

1 1901 WALDO, FRANK. The Blue Hill Meteorological Observatory.

2 1904 ASSMANN, Dr. R. The Temperature of the Air above Berlin (from Oct. 1st, 1902, until Dec. 31st, 1903).

3 1906 WEGENER, KURT. Die Tage mit für Motorballons günstigem Wetter.

4 1906 ROSENTHAL, ELMAR. Ueber starke Regen in St. Petersburg.

5 1910 BIGELOW, Prof. F. H. The Circulation of the Atmospheres of the Earth and of the Sun.

6 1912 WEGENER, Dr. KURT. Die Wirkung der Berge auf eine sie übersteigende Luftsäule.

7 1912 BJERKNES, V. Propositions (à la Commission Internationale pour l'Aérostation Scientifique, Conférence de Vienne, 1912).

8 1913 CENTRAL FLYING SCHOOL. Report on Meteorological Work carried out (17th May—13th August, 1913).

9 1913 ———— Report of Work of the Meteorological Officer at C.F.S. during 1913.

10 1914 CAVE, CHAS. J. P. Upper Air Research.

11 1929 KOPPE, HEINRICH. Von den Gefahren des Luftmeeres.

12 1929 IRKUTSK MAGNETIC AND MET. OBSERVATORY. Transactions: No. 4. *(In Russian, with German translation.)*

13 1931 KALITIN, N. N. The Rôle of the Clouds in Illuminating the Earth's Surface. (*In Russian, with Résumé in French.*)

14 1933 DEFANT, Prof. A. Der Abfluss schwerer Luftmassen auf geneigtem Boden nebst einigen Bemerkungen zu der Theorie stationärer Luftströme.

15 1935 MIDDLETON, W. E. K. The Principles underlying the Choice of Visibility Marks.

16 1936 FERIET, J. KAMPÉ DE. La Turbulence Atmosphérique.

17 1937 BAGNOLD, R. A. The Size-Grading of Sand by Wind.

18 1937 SERRA, A. B., and BARBOSA. The Normal Atmosphere above Rio de Janeiro.

19 1937 BRUN, EDMOND. L'Antigivrage et le Dégivrage des Avions par Chauffage Electrique. (Interleaved French/English.)

20 ? U.S. WEATHER BUREAU. Cloud Forms. (Sheets of Photographs.)

21 1938 *IMPERIAL REVIEW* (*Dec.*). *Ice Formation on Aircraft. The Action of Kilfrost Paste.*

22 1939 BRITISH TYRE & RUBBER Co. B.T.R. De-Icers for Aircraft.

Section b. Stratosphere and Rocket Flying.

1 1930 BRACKENBURY, E. W. High-Speed Propulsion for Aircraft.

2 1940 CHIPLONKAR, M. W. The Distribution of Temperature in the Lower Stratosphere.

Y.15.i. NAVIGATION.

Section a. Navigation.

1 1911 SUPLEE, HENRY H. Methods of Determining Aeroplane Altitudes.

2 1911 WILLSON, ROBERT W. Determination of the Altitude of Aeroplanes.

3 1922 DUVAL, A. B., and HÉBRARD, L. Traité pratique de Navigation Aérienne.

4 1922 ———————— Practical Treatise on Air Navigation. (Typewritten translation of No. 3.)

5 1923 PREUD'HOMME, A. Les Vols de Nuit sur les Routes Aériennes.

6 1923 AERONAUTICAL CHAMBER OF COMMERCE OF AMERICA. Special Report on Night Flying Experiments conducted by the U.S. Air Mail Service.

7 1927 COUTINHO, G., & CASTILHO, J. Navigation des Avions du Service Commercial pour l'Amérique du Sud.

8 1929 KOPPE, HEINRICH. Luftnavigierung und die Arbeiten des Navigierungs-Ausschusses der W.G.L.

9 1938 THEODORIES, PH. La Navigation Aérienne par Vent Variable.

10 1939 CHICHESTER, FRANCIS. Raiding by Celestial Navigation.

Section b. Instruments and Automatic Pilots.

1, 2 1929 KOPPE, HEINRICH. Die Bedeutung der Messtechnik für Luftfahrt. (2 copies.)

3 1930 MARMONIER, L. La Stabilité et la Direction Automatiques des Avions.

4 ?1931 ———————— Stabilisateur automatique pour Aéroplane, à actionnement Pneumatique.

5 1933 BECKER, L. On a new Aircraft-Sextant for use with Visible Horizon.

6 1938 J.V.W. CORPORATION. Link Aviation Trainer.

7 ? JUNKERS - FLUGZEUG-WERKE. Navigation und Flugzeug-Ausrüstung.

8 ? GYROECTOR, G.m.b.H. Wirkungsweise des "Gyroector."

Section c. Aircraft Markings and Signals.

1 1934 REICHSLUFTFAHRTMINISTERIUM. Nachrichten für Luftfahrer, No. 13, 1934. Abzeichen für Zivil- und Militär-Luftfahrzeuge.

Y.15.ii. NAVIGATION AND AIR LAW.

(Air Ministry Publications.)

1 **Obsolete Regulations.** Envelope containing:—
3 copies Draft of International Convention (1919) with one copy of typewritten amendments.
Air Navigation Directions Nos. 1, 6, 6a, 11, 11b, 11c, 11d, 12.
Air Navigation Regulations, 1919.
Air Navigation Consolidation Order, 1923 (amended to 1932).

1a Convention relating to International Air Navigation (1919). Cmd. 266.
Railway Companies Arbitration Act, 1859.
Arbitration Act, 1889.

2 Convention for the Regulation of Aerial Navigation (13 Oct., 1919). Cmd. 670.

2a Protocols regarding the Amendment of the Convention relating to the Regulation of Air Navigation of Oct. 13, 1919. (Brussels, June 1, 1935.)

3 Folder containing:—
2 copies Air Navigation Act, 1920.
2 ,, ,, ,, 1936.

4 Air Navigation Bill. Presented by Sir Philip Sassoon to the House of Commons, 19 Dec., 1935.
Lords' Amendments to the Air Navigation Bill, 28 July, 1936.

5 Folder containing Air Navigation (Consolidation) Order (1935 ed.) and subsequent Amendments.

6 Folder containing:—
Air Navigation Directions (A.N.D. 13, 13A, 14, 14A, and subsequent additions).
Air Navigation Regulations, 1937-39, with additions as received.

7 Folder containing International Sanitary Convention (Cmd. 4938), 1933. (2 copies.)

8 Folder containing:—
Civil Air Ensign Order, 1937.
Air Navigation (Licensing of Public Transport) Order, 1938, and Amendments.
Carriage by Air Act, 1932; Carriage by Air (Parties to Convention) Order, 1939.
Air Council (Membership, Duties and Business), 1923.

9 Folder containing:—
Air Navigation (Amendment) Orders as adapted to Jersey, Guernsey, Isle of Man.
Air Navigation Order (Colonies, Protectorates, etc.), 1927.
Investigation of Accidents (Jersey and Guernsey) Regulations, 1926.

10 Folder containing:—
Air Navigation (Investigation of Accidents) Regulations, 1925, with subsequent Amendments.
Merchant Shipping, Prevention of Accidents. (1910.)
Aircraft Wreck and Salvage Order, 1938.
Order adopting the Merchant Shipping Act, 1894, to Aircraft.

Y.15.iii. CIVIL AIR NAVIGATORS' LICENCES.

(First and Second Class.)

Section a. General Information.

Syllabuses of First and Second Class Examinations.
Prospectuses of Schools preparing for Examination.
(*This information will be changed and brought up to date as and when necessary.*)
C.A. Pub. 2. The Licensing of Civil Aerial Navigators. (Jan. 1921.)

Section b. Second Class Licence. Examination Papers.

1925, September.
1926, January, April, September, December.
1927, October, December.
1928, April.
1930, July, October.
1935, March.
1937, April.
1938, April.
1934, 1935, 1936, March (in 1 Vol.).
1936, March.

Section c. First Class Licence. Examination Papers.

1928, July, December.
1929, April.
1935, March.
1936, June/July.
1937, April.
1938, April.

Y.16. PHOTOGRAPHY & AIR SURVEY.

1 1903 *ILLUSTRATED SCIENTIFIC NEWS. A Novel Telephotographic Apparatus.*
2 1908 DOLEZAL, Prof. E. Ueber die Bedeutung der photographischen Messkunst.
3 1908 OEST. GES FUER PHOTOGRAMMETRIE. Internationales Archiv für Photogrammetrie.
4 1913 KAMMERER, G. La Photogrammetrie Aerienne.
5 1914 ———— Der Topograph im Ballon.
6 1924 WINTERBOTHAM, Col. H. St. J. L. Stereoscopic Plotting Machines for use in Photographic Surveying.
7 1928 BOURNE, R. Aerial Survey in Relation to the Economic Development of New Countries, with special Reference to an Investigation carried out in Northern Rhodesia.
8 1931 GRUBER, Otto v. Ueber die photogrammetrische Ausrüstung des "Graf Zeppelin" auf der Arktisfahrt, 1931.
9 1932 BLEE, Henry H. Air Navigation Maps.
10 1934 HEMMING, H. Modern Methods of Air Survey and Exploration.
11 1934 ITALIAN STATE TOURIST DEPT. Italy seen from the Sky.
12 1935 *IMPERIAL REVIEW. London from the Clouds (Photograph).*
13 1937 HEMMING, H. Air Survey as a Factor in Empire Development.
14 1938 *IMPERIAL REVIEW. Aerial View of Sydney. (Photograph.)*
15 1938 *CANADIAN INFORMATION BUREAU. Mapping from the Air in Canada.*
16 1938 RUBE, Kurt. Modern Instruments for Aero-Photogrammetry.
17 1939 BURCHALL, Sqd. Ldr. P. R. Air Survey for Railway Electrification Schemes.
18 1939 IMPERIAL AIRWAYS, LTD. Film Show. (Details of 4 Films describing Imperial Airways.)

Y.17. WARFARE.

Section a. Prior to 1914.

1 1865 BRITISH GOVERNMENT. Accession of the British Government to the Convention signed at Geneva, August 22nd, 1864, for the Amelioration of the Condition of the Wounded in Armies in the Field.
2 1902 BRUCE, Eric H. Stuart. The Use of Balloons in War.
3 1904 FULLERTON, Lt.-Col. J. D. Report on Aerial Navigation.
4 1909 STONE, Col. F. G. Defence of Harbours against Naval Airships.
5 1912 BRITISH ARMY. Military Aeroplane Competition, 1912. Report of Judges Committee.
6 1912 ———— Memorandum on Naval and Military Aviation.
7 1914 THE NAVY LEAGUE. The Hydro-Aeroplane in its relation to National Defence.

Section b. The Great War (1914-18).

1 1915 JOHNSON, Hill. The Aeroplane and War.

2 1915 BANNERMAN-PHILLIPS, H. Aircraft in Warfare.

3 1915 "ARMS AND EXPLOSIVES." Aeroplanes as Targets.

4 1916 BRITISH ARMY. Final Report of the Committee on the Administration and Command of the Royal Flying Corps.

5 1916 SECRETARY OF STATE. Report of the Committee . . . to conduct Experiments to Test the Value of Dry Powder Fire Extinguishers as compared with Water and other "First Aid" Appliances for extinguishing or effectively controlling Fires such as are likely to be caused by Bombs.

6 1918 MINISTRY OF MUNITIONS. Camouflage of Aeroplanes for Observation.

7 1919 PRESTON, RUPERT L. Essay on Enemy Aircraft Exhibition, Islington.

Section c. From 1919 Onwards. (Alphabetical.)

Air Raids.

Report on Occupancy Tests of Air Raid Shelters for Factory Workers. (1939.) J. & E. Hall.

How Great is the Air Raid Peril? Capt. Liddell Hart. (*SUNDAY EXPRESS*, 23/7/39.)

Why the Bombers stay at home. (*EVENING STANDARD*, 2/10/39.)

Hitler's East Coast Raids. (*EVENING STANDARD*, 22/2/40.)

R.A.F. Raids on Germany. (*EVENING STANDARD*, 29/2/40.)

Australia.

Defence Forces: Aeroplane Manufacturing. (*IMPERIAL REVIEW, April* 1939.)

Anti-Aircraft Guns.

(Making the New Anti-Aircraft Guns: Reprint from "Machinery," Jan./Feb. 1939.)

Armament.

Aircraft Armament (with section drawings of 4 fighter planes). ILLUSTRATED LONDON NEWS, June 10, 1939.

Ballistics.

1936 OTTEN, G. Ballistiche gegevens van Vliegtuigbommen. (Ballistic Data regarding Aircraft Bombs.)

BELGIAN MILITARY AVIATION. Revue Militaire Belge (XXVe Anniversaire de l'Aviation Militaire). June 1939.

BOMBS AND BOMBING. Modern R.A.F. Methods and Types of Projectile. ILLUSTRATED LONDON NEWS, 10/6/39.

———————— *Bombing from Aircraft. THE ENGINEER*, 13/9/40.

Balloon Barrage.

The Balloon Barrage Explained. 1940.

Bombing.

Bombing by Aircraft. 1940.

Bren Machine Gun.

(The Manufacture of the Bren Light Machine Gun. Reprint from "Machinery," June/July 1938.)

Canada.

A Great Imperial Gesture (Aircraft Building in Canada). (*IMPERIAL REVIEW, Nov.* 1939.)

China.

Inaccurate Japanese Air-Bombing in China. ILLUSTRATED LONDON NEWS, 16/10/37.

Chiefs of Staff.

(*Photographs*). *NEWS REVIEW*, 18/1/40.

England.

Air Defence and the Motor Industry. (*IMPERIAL REVIEW, June* 1936.)

The Air is now our First Line of Defence. (*IMPERIAL REVIEW, Nov.* 1938.)

France.

How to tell the Raiders. (*Silhouettes of 4 French warplanes.*) (*DAILY EXPRESS*, 17/8/39.)

Searchlights.

Our Searchlight System. 1941.

Obsolescence.

Aircraft Obsolescence. ("*THE ENGINEER*," 23/2/40.)

Russia.

These are the Facts about Russia's Air Force. By Lord Forbes. (*DAILY EXPRESS*, 2/5/39.)

Trained Pilots are Scarce. (*DAILY EXPRESS*, 1/1/40.)

More than half Red planes obsolete. (*DAILY EXPRESS, Feb.* 1940.)

U.S.A.

War confronts America. (*Pictures of American Planes for R.A.F.*) (*CHRISTIAN SCIENCE MONITOR*, 23/9/39.)

WOMEN AND THE WAR: In Britain; In France. (*CHRISTIAN SCIENCE MONITOR*, 23/9/39.)

WARPLANE MARKINGS. (*Coloured sheet—undated.*)

Y.18. WIRELESS AND ELECTRICITY.

Section a. Wireless.

1 1902 *ILLUSTRATED SCIENTIFIC NEWS* (*A. Frederick Collins*). *Some new Detectors for Wireless Telegraphy.*

2 1903 ———————— *Trans-Atlantic Wireless Telegraphy.*

3 1903 ———————— *Music of the Spheres.*

4 1903 ———————— *Wireless Telegraphy: The Lodge-Muirhead System. By E. S. Grew.*

5 1903 ———————— *Isolating Wireless Messages.*

6 1903 ———————— *Mr. Andres Bull's Selective System.*

7 1903 ———————— *Professor Fessenden's System.*

8 1903 ———————— *The Collins Wireless Telephone.*

9 1903 ———————— *Wireless Telegraphy between Poldhu and the Royal Institution.*

10 1903 ———————— *The De Forest Wireless Telegraph System.*

11 1903 ———————— *Magnetic Detectors in Space Telegraphy. By Ernest Wilson.*

12 1903 *ILLUSTRATED SCIENTIFIC NEWS. A Novel Scheme for Wireless Telegraphy.*
13 1903 ———— *The Stone System of W.T. (Selective Signalling).*
14 1904 ———— *The Rôle of the Earth in Wireless Telegraphy.*
15 1903 *THE TIMES (Rev. J. M. Bacon). Telegraphy Mysteries.*
16 1909 *DAILY MIRROR. Wireless Telegraphy to aid Channel Aeroplane Flight.*
17 1909 ? *(Probably THE TIMES). Italy: Radiotelegraphy and Radiotelephony.*
18 1909 *THE TIMES. Mr. Edison's views.*
19 1911 *MORNING POST. Wireless Telegraphy from Aeroplanes.*
20 ? ? *(Unidentified photograph representing a soldier with a portable wireless set.)*
21 1924 PHYSICAL SOCIETY OF LONDON and ROYAL METEOROLOGICAL SOCIETY. Ionisation in the Atmosphere and its Influence on the Propagation of Wireless Signals.
21a 1927 DIECKMANN, Max. Strahlungsdichte und Empfangsfläche.
21b 1934 AIR MINISTRY. Press notes on Sir Ph. Sassoon's inauguration of the Micro-Ray Radio Link between Lympne and St. Inglevert.
21c 1935 ———— Civil Aviation Wireless Plans: openings for Ex-Airmen Operators.
22 1936 *IMPERIAL REVIEW. Wireless on Empire Routes.*
23 1936 ———— *The Colonies like G.E.C. Radio Equipment.*
24 1936 DENMAN, Roderick. Wireless and the Aerodrome Owner.
25 1938 U.S. DEPT. OF AGRICULTURE. Distribution of Weather Information by Radio.
26 1937 FLEMING, Sir A. Guglielmo Marconi and the Development of Radio-Communication.
27 1938 *IMPERIAL REVIEW. Canada's Safe Air Routes. Radio Beams for Night Flying.*
28 1939 HECHT, N. F. S. Radio in Aviation: A General Survey, with special reference to the Royal Air Force.
29 1937 LORENZ A-G., Berlin. Lorenz Flugzeug - Blindlandungs - Anlagen: Empfänger.
30 1937 ———— Lorenz Blind Landing Receiver.
31 1937 ———— Lorenz Blind Landing Beacon.
32 1940 HODGSON, A. D. Civil Air
33 Transport Communication. (2 copies.)

Section b. Electricity.

1 1925 WIGAND, Dr. A. Luftelektrische Untersuchungen bei Flugzeugaufstiegen.
1a 1929 KLOSS, E. Verhalten von Umformern bei Netzstörungen.
1b 1928 A. E. G. BELEUCHTUNGSKOERPER. Die grossen Glasgleichrichter der AEG.
1c 1929 PETERS, Dr. Wilhelm. Neue Verfahren zum Synchronisieren von Synchronmaschinen und Synchronkraftwerken.
2, 3 1936 GAS ACCUMULATOR CO. "Aga" Course-Indicating Airway Beacon.
4 1939 MIDDLETON, W. Knowles. On the Theory of the Ceiling Projector.
5 1939 WRIGHT, Johnstone. Inaugural Address to the Institution of Electrical Engineers, Oct. 26th, 1939.

Y.19. AIR MINISTRY D.T.D. SPECIFICATIONS.

(As per current list, kept in the front of box-file.)

Y.20.i. AIR ESTIMATES.

Air Estimates Speeches, etc.

1931 Mr. F. Montague.
1934 Sir Philip Sassoon.
1934 Lord Londonderry (Speech on Lord Hutchison's Motion for a Ministry of Defence: House of Lords, 14/3/34).
1936 Sir Philip Sassoon.

Air Estimates.

1922/23
1923/24
1925/26 (With accompanying Memorandum by Sec. of State for Air.)
1935
1936 (With accompanying Memorandum by Sec. of State for Air.)
1936 Supplementary Estimate. (3 copies.)
1937 (With accompanying Memorandum by Sec. of State for Air.)
1938 (With accompanying Memorandum by Sec. of State for Air.) (2 copies each.)

Miscellaneous.

Cmd. 5296 Note on the Policy of His Majesty's Government in relation to the Production of Aero-Engines. (Oct. 1936.)
———— Air Services Appropriation Account, 1935. (Published 1937.)
Cmd. 5374 Statement relating to Defence Expenditure. 1937. (2 copies.)
Cmd. 5368 Defence Loans: Memorandum on the Proposed Resolution. 1937.

Y.20.ii. PARLIAMENTARY DEBATES, ETC.

Parliamentary Debates.

Vol. 152, No. 31, 21/3/22. Air Estimates, 1922/23. Control of R.A.F.
Vol. 319, No. 42, 27/1/37. Inadequacy of Air Defences.
No. 45, 1/2/37. Miscellaneous.
Vol. 320, No. 57, 17/2/37. Defence Loans.
No. 58, 18/2/37. Defence Loans.
Vol. 321, No. 77, 17/3/37. Air Estimates, 1937.
No. 80, 22/3/37. Air Estimates, 1937.

Vol. 341, No. 8, 17/11/38. Air Defence Debate. (Col. Moore-Brabazon.)
Vol. 348, No. 117, 12/6/39. Civil Aircraft Production Committee.
Vol. 357, No. 30, 28/2/40. Civil Aircraft Development Committee.
Vol. 358, No. 36, 7/3/40. Air Estimates, 1940, and Supplementary Estimate, 1939. (2 copies.)
Vol. 364, No. 105, 20/8/40. Civil Defence: Air Raid Warnings, War Situation.
Vol. 365, No. 110, 18/9/40. R.A.F. Newspaper Articles; Air Defence Cadets Corps.

Air Conference Reports.

Proceedings of the Air Conference, 1920. With Appendices. (Cmd. 1157.)
Proceedings of the Second Air Conference, held on 7th and 8th Feb. 1922. (Cmd. 1619.)
Proceedings of the Third Air Conference, held on 6th and 7th Feb. 1923. (2 copies.) (Cmd. 1848.)

Miscellaneous.

Cmd. 5254. Report of the Board of Enquiry appointed by the Prime Minister to investigate certain discussions engaged in by the Permanent Secretary to the Air Ministry. (Sir Christopher Bullock.) 1936.
Cmd. 5255. Minute by the Prime Minister on the above Report. 1936.
Cmd. 5237. Air Ministry. Civil Air Transport Service. Note by the Secretary of State for Air on the principal provisions proposed to be embodied in an agreement with Imperial Airways, Ltd., for a regular air service between Bermuda and New York. July, 1936.
C.196, M.125, 1938, VIII. LEAGUE OF NATIONS. Committee for Communications and Transit. Report to the Council on the Work of the Twenty-Second Session, held at Geneva from June 6th to 9th, 1939.
Cd.9218. Reports of the Civil Aerial Transport Committee, with Appendices. 1918.
Cmd. 1739. Civil Aviation Advisory Board. First Report on Imperial Air Mail Services. 1922.
Cmd. 1811. Civil Air Transport Subsidies Committee. Report on Government Financial Assistance to Civil Air Transport Companies. 1923.

Y.21. BADEN-POWELL COLLECTION.

(Works by Major B. Baden-Powell, arranged alphabetically under Titles.)

Aeroplanes and Flying Machines. (Article in "The Car" Magazine: Sept. 1903.)
(The) Conquest of the Air. (Article in The United Service Magazine. April 1897.)
(The) Exploration of the Air. (From Quarterly Journal of the Royal Meteorological Society. Vol. XXXIII, No. 143. July 1907.) 2 copies.
How Airships are likely to affect War. (Lecture to Royal United Service Institution, Dec. 8th, 1909; also second copy, in Journal of the Royal United Service Institution, May 1910.)
Kites: their Theory and Practice. (In Journal of the Society of Arts, March 4th, 1898.)
Law in the Air. (In The National Review. March 1909.)
Military Ballooning. (Lecture to Royal United Service Institution, June 1st, 1883.)

Y.22. PUBLICATIONS OF THE GUGGENHEIM AERONAUTICS LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY.

5 MILLIKAN, C. B. Wind-Tunnel at the California Institute of Technology.
9 BATEMAN, H. Irrotational Motion of a Compressible Inviscid Fluid.
11 ——— Solutions of a certain Partial Differential Equation. 1931.
12 ——— The k-Function: a particular case of the Confluent Hypergeometric Function. 1931.
14 MILLIKAN, C. B. The Boundary Layer and Skin Friction for a Figure of Revolution. 1932.
16 KARMAN, Th. v., SECHLER and DONNELL. Survey of the Problems of Thin-Walled Structures. 1932.
18 KLEIN, A. L. The Effect of Fillets on Wing-Fuselage Interference. 1932.
23 BRAHTZ, J. H. A. Stress Distribution in a re-entrant Corner.
24 BIOT, Dr. M. Calculation of the Stresses occurring in a Building during Earthquakes.
25 ——— Critical Torsional Oscil-
25a lations of a Rotating Accelerated Shaft. (Original Edition and Reprint.)
26 KARMAN, Th. von. Quelques Problèmes actuels de l'Aérodynamique.
27 SECHLER, E. E. The Ultimate Strength of Thin Flat Sheets in Compression.
29 TOLLMIEN, W. Die karmansche Aenlichkeitshypothese in der Turbulenztheorie und das ebene Windschattenproblem.
32 ——— On the Turbulence Statistics in Burgers' Phase Space. 1933.
33 MILLIKAN and KLEIN. The Effect of Turbulence: an Investigation of Maximum Lift Coefficient and Turbulence in Wind Tunnels and in Flight.
34 KARMAN, SECHLER and DONNELL. Survey of Problems of Thin-Walled Structures. 1933.
I. (Donnell). The Problem of Elastic Stability.
II. (Sechler). Strength of Thin Metal Structures beyond the Stability Limit.
III. (Kármán). Analysis of some Typical Thin-Walled Structures.
35 BIOT, M. Korrektur für das Quermoment von Tragflügeln bei Untersuchungen im Windkanal mit Kreisquerschnitt.

36 SECHLER, E. E. A Preliminary Report on the Ultimate Compressive Strength of Curved Sheet Panels.

37 KARMAN, TH. VON. Turbulence and Skin Friction. 1934.

38 DONNELL, L. H. Stability of Thin-Walled Tubes under Torsion. (N.A.C.A. Rep. 479.)

39 SADRON, CH. Hydrodynamique Expérimentale: sur une nouvelle Méthode Optique d'Exploration d'un Champ de Vitesses Bidimensionnel.

40 KARMAN and MILLIKAN. The Use of the Wind Tunnel in Connection with Aircraft Design Problems. 1934.

42 KARMAN, TH. VON. Some Aspects of the Turbulence Problem. 1934.

43 WATTENDORF, F. Some experimental Investigations of Flow in Curved Channels. 1934.

44 SADRON, C., and ALCOCK. An Optical Method for measuring the Distribution of Velocity. 1934.

45 WATTENDORF, and KUETHE. Investigations of Turbulent Flow by means of the Hot-Wire Anemometer. 1934.

46 BRIDGET, JEROME & VOSSELLER. Some new experiments on Buckling of Thin-Wall Construction. 1934.

47 BIOT and SMITH. Etude Photo-Elastique des Tensions de Contraction dans un Barrage. 1933.

48 BIOT, M. Theory of Vibration of Buildings during Earthquake. 1934.

49 MILLIKAN, C. B. Further Experiments on the Variation of the Maximum-Lift Coefficient with Turbulence and Reynolds Number. 1934.

50 DONNELL, L. H. A new Theory for the Buckling of Thin Cylinders under Axial Compression and Bending. 1934.

51 KARMAN and MILLIKAN. On the Theory of Laminar Boundary Layers involving Separation. (N.A.C.A. Rep. No. 504.)

52 MOORE, N. B. Application of Kármán's Logarithmic Law to Prediction of Airship Hull Drag. 1935.

54 WATTENDORF, F. L. A Study of the Effect of Curvature on fully developed Turbulent Flow. 1935.

55 KARMAN and MILLIKAN. A Theoretical Investigation of the Maximum Lift Coefficient. 1935.

56 ALCOCK and SADRON. An Optical Method for Measuring the Distribution of Velocity Gradients in a Two-Dimensional Flow. 1935.

57 DUWEZ, POL. On the Plasticity of Crystals. 1935.

59 ROOT, L. E. Dynamic Longitudinal Stability Charts for Design Use. 1935.

60 ROCKEFELLER, W. C. Optimum Flight Path in Air Transport Operation. 1935.

61 KARMAN, TH. VON. Some Aspects of the Turbulence Problem. 1935.

63 KUETHE, A. M. Investigations of the Turbulent Mixing Region formed by Jets. 1935.

64 JENNEY, WILLIAM. The Effect of Horizontal Variations in Center of Gravity Position on the Static Longitudinal Stability of Airplanes. 1935.

65 RUSSELL, McKOY and MILLIKAN. Wind Tunnel Tests on a High Wing Monoplane with Running Propeller. 1936.

66 MILLIKAN, C. B. A Theoretical Calculation of the Laminar Boundary Layer around an Elliptic Cylinder, and its comparison with Experiment. 1936.

68 KLEIN, A. L. Methods of Cabin Supercharging and their necessary Control Systems. 1935.

69 ALCOCK, E. D. The Effect of an Electric Field on the Viscosity of Liquids. 1936.

70 MILLIKAN, C. B. On the Stalling of Highly Tapered Wings. 1936.

71 WATTENDORF, F. L. Investigations of Velocity Fluctuations in a Turbulent Flow. 1936.

72 WHITE, R. J., and ANTZ, H. M. Tests on the Stress Distribution in Reinforced Panels. 1936.

73 MALINA and JENNEY. Characteristics of Braked, Locked and Free-Wheeling Two- and Three-Bladed Propellers. 1936.

74 ROCKEFELLER, W. C. High Altitude Transport. 1936.

75 KARMAN, TH. VON. The Problem of Resistance in Compressible Fluids. 1935.

76 WHITE and MARTIN. Charts for Calculating the Performance of Airplanes having Constant-Speed Propellers. (N.A.C.A. Tech. Note 759.) 1936.

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4 The Decoration of Tinplate by Printing and Varnishing. W. E. Hoare.
5 Fusible Alloys Containing Tin. E. J. Daniels.
6 The Wetting of Metals by Metals, with particular reference to Tinning and Soldering. E. J. Daniels and D. J. Macnaughtan.
7 The Hot-Tinning of Fabricated Articles. E. J. Daniels.

Series D.

3 Mechanical Properties of Some Tin Bronzes. Dr. H. Lepp.

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6 The Role of Technical Information in Industrial Research and Development. C. E. Homer and E. S. Hedges.

Reports.

2nd General Report, 1937.
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55 The Determination of Cadmium in Tin-Rich Alloys. Prof. D. Hanson and W. T. Pell-Walpole.

56 The Electrodeposition of Tin from Acid Sulphate Solutions. A. W. Hothersall and W. N. Bradshaw.

57 Mechanical Properties of some White Bearing Metals and other Tin-Base Alloys at Various Temperatures. C. E. Homer and H. Plummer.

58 The Tensile Properties of a Series of White Metal Bearing Alloys at Elevated Temperatures. H. Greenwood.

59 Variation in Thickness of the Tin Coating of Tinplate, and its effect on Porosity. W. E. Hoare.

60 A Plane Bending Apparatus with Interferometer Strain Recorder for Metallurgical Investigations. J. W. Cuthbertson.

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63 The Corrosion of Tin in nearly Neutral Solutions. T. P. Hoar.

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68 The Influence of the Difference of Orientation of Two Crystals on the Mechanical Effect of their Boundary. Bruce Chalmers.

69 The Colorimetric Determination of Tin by means of Toluene-3: 4-dithiol ("Dithiol.") R. E. D. Clark.

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73 "Frostiness" in Plumbers' Solder. F. A. Rivett.

74 Research on Thin Layers of Tin and other Metals. IV. Further Investigation on Corrosion by Oils. P. J. Haringhuizen and D. A. Was.

75 Some Factors that may determine the Service Life of Tin-Base Bearing Metals. D. J. Macnaughtan.

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82 Electrodeposition of Tin from Alkaline Solutions. S. Baier and R. M. Angles.

83 The Electrodisposition of Tin from Acid Sulphate Solutions. II. A. W. Hothersall and W. N. Bradshaw.

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87 Embrittlement of Tin at Elevated Temperatures and its relation to Impurities. C. E. Homer and H. Plummer.

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91 Anodic Films on Tin in Sodium Hydroxide Solutions. R. Kerr.

92 Electro-Tinning. S. Baier.

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94 (*Annual Report*, 1938—*see above.*)

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2 1903 The Lanchester Motor and Carriage. Part I. Descriptive Manual.

3 1903 The Lanchester Motor and Carriage. Part II. Driving Manual.

4 1905 The Pendulum Accelerometer.

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8 1909 Tractive Effort and Acceleration of Automobile Vehicles on Land, Air and Water.

9 1909 Mechanical Flight. (Newspaper cuttings from TIMES ENGINEERING SUP.)

10 1910 Factors that have Contributed to the Advance of Automobile Engineering.
11 1912 Facsimile Reproduction of the National Physical Laboratory's Report on Daimler-Lanchester Worm Gears.
12 1914 Engine Balancing.
13 1914 Worm Gear.
14, 15 1915 The Cylinder Cooling of Internal Combustion Engines.
16 1916 Worm Gear and Worm Gear Mounting.
17 1916 Rise and Fall of the French Air Ministry.
18 1917 The Air Defence of London.
19 1917 Industrial Engineering: Present Position and Post-War Outlook.
20 1918 Industrial Economics during and after the War.
21 1919 The Aftermath of the War: Economic and Industrial Problems.
22 1922 An Investigation of Certain Aspects of the Two-Stroke Engine for Automobile Vehicles.
23 1923 Epicyclic Gears.
24 1928 Automobile Steering Gear—Problems and Mechanism.
25 1928 India-Rubber as an Auxiliary to Suspension.
26 1929 Coil Ignition.
27 1936 Motor Car Suspension and Independent Springing.
28 1936 A Study of the Dynamo based on Dimensional Theory.
29 1936 A King's Prayer and other Poems. (Pseudonym: PAUL NETHERTON-HERRIES.)
30, 31, 32 1937 The Treatment of Problems in Engineering by Dimensional Theory. (3 copies.)
33 1937 The Gas Engine and After.
34 1938 Independent Springing.
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2 Della Quota massima di Volo degli Aeroplani. 1917.
3 Del Costo dei Trasporti Aerei nei Servizi Pubblici. 1921.
4 L'Avvenire dei Trasporti Aerei nei Servizi Pubblici. 1921.
5 L'Impiego dei Dirigibili nei Trasporti di Passeggieri. 1921.
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7 Alcune primi Risultati di Collaudo dell' Aeronave "N.1." 1923.
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9 Della Quota di Tangenza di un'Aeronave. 1924.
10 Sugli ultimi Progressi realizzati in Italia nella Tecnica Costruttiva dei Dirigibili. 1923.
11 Il Volo Traspolare. 1925.
12 Contributo sperimentale allo studio delle Variazioni di Carico Utile di un'Aeronave in dipendenza delle Condizioni Atmosferiche ambienti. 1925.
13 Sistema "Nobile" per Atterramento ed Ammaramento meccanico di Aeronavi. 1925.
14 Sullo Sviluppo delle Costruzioni dei Dirigibili in Italia. 1926.
15 Il dirigibile italiano nelle sue più recenti realizzazioni: il tipo "N." 1926.
16 The Dirigible and Polar Exploration. 1928.
17 Momenti statici, forze portanti dinamiche, angoli di barra singolari e velocità d'inversione di un Dirigibile "N." 1937.
18 Determinazione delle potenze necessarie e delle potenze disponibili per il Volo. ?1937.
19 Sulle Variazioni termiche del Gas contenuto nella Carena di un Aeronave e conseguenti Variazioni di Forza ascensionale. 1937.
20 Alcuni questioni attinenti alla Meccanica del Volo dei Dirigibili. 1938.
21 La Pressione del Gas nei Dirigibili. 1939.
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23 Notizie e Pubblicazioni Scientifiche. 1937.

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3 1932 AIR MINISTRY. Royal Air Force Manual. (A.P. 957.) 2nd Ed.
4 1939 WILLIAMSON, R. Birth of the R.A.F.
6 1939 ILLUSTRATED LONDON NEWS. Special "Royal Air Force" Number. June 10th. (Articles extracted also for Y.3.ii and Y.17.)

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1936 *Nov. "Power" Boats for R.A.F.: Fast and Seaworthy Craft in Rough Weather.*
1937 *July. Impressing the Foreign Observers.* (*Hendon.*)
1937 *July. Two Miles Aloft.* (*Flt.Lt. Adam's altitude record:* 53,937 *ft.*)
1937 *Aug. Britain's Fastest Bombers.* (2 *Bristol Blenheims sold to Finland.*)
1938 *Feb. Edinburgh to London in under an Hour.* (*Hawker Hurricanes.*)
1938 *May. South Africa's Air Power* (200 *warplanes purchased from England.*)

1938 *Nov. Lessons of Britain's Long-Distance Aerial Record.*
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2 Enlistment Forms for R.A.F. Reserve. (CW.H.1—R.N. Volunteers; 1381, 1384, 1764, 1765.)
3 Apprentices and Boy Entrants. (A.P. 134, A.M. Communiqués 4049, 4325, 4422, 4521; A.M. Pamph. 9, 15, 54; A.M. Forms 1417, 1421.)
4 R.A.F. Reserve and R.N.V. (Sup.)R. (A.P. 938; A.M. Pamph. 2, 56, 62, 63; A.M. Communiques 4533, 4738; notice re Auxiliary Air Force Personnel, Qualifications for R.N.V.R., Engineering Section.)
5 Stores Branch, Accountant Branch and Medical Officers. (A.M. Pamph. 17, 18 and 25.)
6 R.A.F. College, Cranwell. (A.P. 121, Air Min. Circular 1936, and notice re Lord Wakefield Scholarship, 1933.)
7 Permanent Commissions in General Duties Branch; RATES OF PAY. (A.P. 879 and 904; A.M. Pamph. 8; Memos. for issue with A.P. 121 and 904, and with A.M. Pamph. 1 and 14; Form 434.)
8 Short Service Commissions. (A.M. Pamph. 13.)
9 General Recruiting Information. (2 circulars; A.M. Pamph. 27. A.M.O. 364—Careers of Airmen: Fitters Aero and Metal Riggers.)

Y.27.ii. **ROYAL AIR FORCE.**

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Y.28. **PUBLICATIONS OF THE LABORATORIO DELLA R. SCUOLA DI INGEGNERIA DI TORINO. (R. POLITECHNICO DI TORINO.)**

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Studio sull'Elica autorotante. C. Ferrari and G. Gabbrielli.
Un Metodo approssimato per l'Adattamento dell'Elica posteriore di un Sistema di due Eliche in tandem. G. Gabbrielli.
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16 La Costruzione Metallica degli Aeroplani. C. Tapinassi.
17 Concetti e Tendenze nella Costruzione degli Aeroplani Metallici. G. Gabbrielli.
18 Sulla'Ala Deformabile. C. Pasqualini.
19 Sul Comportamento della Chiodatura tra Lamiere in Dural di piccolo Spessore. G. Gabbrielli.
26 La Navigazione Aerea come Mezzo di Trasporto. M. Panetti.
27 Sull'Analogia fra i Campi elettrici e i Campi aerodinamici. C. Ferrari.
28 Prove sperimentali sui tubi di accompagnamento delle Scie d'Elica. Laboratorio Sperimentale.
29 Prove sulla Resistenza oblique dell'Aria a Velocità Balistiche inferiori a quella del Suono. F. Burzio.
30 Nuove formole relative al Comportamento adiabatico del Gas negli Aerostati. M. Panetti.
35 Determinazione alla " Vasca Elettrica " del Campo Aerodinamico intorno a un Proietto. F. Burzio.
36 Prove su di una Pompa ad Ingranaggi. A. Castagna.

37 Sulla Trasformazione conforme di due Cerchi di due Profili Alari. C. Ferrari.
38 Sulla determinazione delle caratteristiche aerodinamiche di un bipiano indefinito costituito da due profili alari dati. C. Ferrari.
39 La resistenza dell'aria per corpi sferici rotanti a velocità prossima a quella del suono. C. Pasqualini.
40 Prove su radiatori per motori di aviazione. A. Castagna.
41 Problemi moderni nella costruzione metallica degli aeroplani. G. Gabbrielli.
42 Esperimenti su eliche per tutti gli stadii di funzionamento e per diversi valori del rapporto passo-diametro. A. Faraboschi.
43 Prove su Proietti intorno alla Velocità del Suono. F. Burzio.
44 Calcolo dei parametri del diagramma della coppie resistenti di un'elica e relazione fra le sue velocità progressiva e di rotazione per coppia motrice costante. M. Panetti.
45 Costruzione geometrica del fuoco di un bipiano e dell'ala equivalente. M. Panetti.
46 Sul campo aerodinamico attorno a solidi di rivoluzione in corrente rettilinea uniforme. C. Ferrari.
47 Notizie su motori a nafta per aerei. A. Castagna.
48 Nuovi problemi sullo studio delle vibrazioni dei mezzi di trasporto. M. Panetti.
49 Sul campo aerodinamico attorno ad un solido siluriforme. C. Ferrari.
50 Sul problema del biplano di apertura finita. C. Ferrari.
52 Prima relazione sul quesito della resistenza dei proietti al movimento nell'Aria. M. Panetti.
53 La stabilità nelle regolazioni di velocità e pressione nelle turbine a vapore. P. Cicala.
55 Sull'influenza dell'elica sulle caratteristiche aerodinamiche dell'ala. C. Ferrari.
57 La regolazione della turbina a vapore a ricupero parziale. P. Cicala.
58 La flessione delle travi con piastra sottile. P. Cicala.
59 Rendiconti sperimentali del Laboratorio di Aeronautica del Regio Istituto Superiore di Ingegneria di Torino. (Prima Serie.)
61 Problema dell'atterraggio con carrelli a reazione combinata elastica e dissipatrice. M. Panetti.
63 Seconda relazione sul quesito della resistenza dei proietti al movimento dell'aria. P. Cicala.
64 Sulla teoria della turbolenza. C. Ferrari.
75 La torsione dei solidi cilindrici a sezione allungata. P. Cicala.
76 Atterramento con ipersostentatori. M. Panetti.
77 Le Azioni aerodinamiche sui profili di ala oscillanti in presenza di corrente uniforme. P. Cicala.
78 Trasmettitori idraulici. P. Aymerito.
79 Amortizzatori idraulici impiegati nei carrelli degli Aeroplani. P. Aymerito.
80 La teoria della turbolenza ed il trasporto della quantita di moto e della vorticità. C. Ferrari.
81 Rendiconti sperimentali del Laboratorio di Aeronautica (2e Serie).
82 Campo aerodinamico a velocità iperacustica attorno a un Solido di rivoluzione a prora acuminata. C. Ferrari.
83 Misure di elasticità coll'uso dei pendoli accoppiati. P. Cicala.
84 Ricerche sperimentali sulle vibrazioni flesso-torsionali di un modello di ala con rigidezze variabili. P. Cicala.
85 Le azioni aerodinamiche sul profilo oscillante. P. Cicala.
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87 Aeroporti. V. Gillardi.
88 Sui moti fluidi turbolenti. C. Ferrari.
89 Considerazioni ed esperienze su di un tipo di motore a rapporto di compressione variabili. A. Capetti.
90 Problemi della tecnica sperimentale alle alte Velocità. M. Panetti.
91 Ricerche dell'influenza dei carburanti sugli oli lubrificanti. A. Capetti and M. Segre.
92 Le oscillazioni flesso-torsionali di un'ala in corrente uniforme. P. Cicala.
93 Errori termici degli altimetri barometrici e loro compensazione. L. Elia.
94 Determinazione della pressione sopra solidi di rivoluzione a prora acuminata disposti in deriva in corrente di fluido compressibile a velocità ipersonora. C. Ferrari.
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*Y.29.ii. **S.B.A.C. NEWS LETTERS (1939).**

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62	1	Advisory Committee on the Langley Aerodynamical Laboratory. (2 copies.) Dr. W. Ritter. 1913.

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62 3 Report on European Aeronautical Laboratories. (2 copies.) L. B. Aldrich. 1919.
69 7 Report on Aircraft Supply of Great Britain. Hodgkins Fund. 1918.
69 9 The Smithsonian Eclipse Expedition of 8/6/18. L. B. Aldrich. 1919.
69 10 The Reflecting Power of Clouds. L. B. Aldrich. 1919.
71 2 A Method of Reaching Extreme Altitudes. R. H. Goddard. 1919.
3 Variation in Solar Radiation and the Weather. H. H. Clayton. 1920.
71 4 The Brightness of the Sky. A. F. Moore and L. H. Abbot. 1920.
5 Observations of the Total Solar Eclipse of May 29, 1919. C. G. Abbot and A. F. Moore. 1920.
72 13 The Melikeron—an approximately Black-Body Pyranometer. L. B. Aldrich. 1922.
78 4 Solar Activity and Long-Period Weather Changes. H. H. Clayton. 1926.
80 2 A Group of Solar Changes. C. G. Abbot. 1927.
81 5 The Relations between the Smithsonian Institution and the Wright Brothers. C. G. Abbot. 1928.
82 3 The Radiation of the Planet Earth to Space. C. G. Abbot. 1929.
6 The Past Climate of the North Polar Region. E. W. Berry. 1930.
7 The Atmosphere and the Sun. H. H. Clayton. 1930.
85 1 Weather Dominated by Solar Changes. C. G. Abbot. 1931.
9 The Determination of Ozone by Spectrobolometric Measurements. O. R. Wulf. 1931.
87 4 The Periodometer: an Instrument for finding and evaluating Periodicities in Long Series of Observations. C. G. Abbot. 1932.
9 Periodicity in Solar Variation. C. G. Abbot and G. Bond. 1932.
18 Sun Spots and Weather. C. G. Abbot. 1933.
89 2 The Latitude Shift of the Storm Track in the 11-year Solar Period. C. J. Kullmer. 1933.
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5 Forecasts of Solar Variation. C. G. Abbot. 1933.
15 World Weather and Solar Activity. H. H. Clayton. 1934.
92 8 Samuel Pierpont Langley. C. G. Abbot. 1934.
12 Remarkable Lightning Photographs. C. G. Abbot. 1934.
13 The Standard Scale of Solar Radiation. C. G. Abbot and L. Aldrich. 1934.
93 4 Pioneer Wind Tunnels. (2 copies.) N. H. Randers-Pehrson. 1935.
94 10 Solar Radiation and Weather Studies. C. G. Abbot. 1935.

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81 Vertical currents in the first few Kilometres over Poona and their possible effect on the measures of Upper Winds made by Pilot Balloons assumed to rise at a known Constant Rate. K. P. Ramakrishnan.

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2 ?1912 SCHWARZ. Lecture on Heavy-Oil Engines.

3 1912 JUNKERS, H. Augmentation of Output in Internal Combustion Engines.

4 1921 JUNKERS A-G. Transportation by Junkers Metal Aircraft.

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6 1924 SACHSENBERG, G. The Political Basis of Air Transport.

7-9 1924 MADER, O. Betrachtungen über den Flugzeugbau. (3 copies.)

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29 1926 ———— Stellungnahme zu den Ergebnissen des Deutschen Seeflug-Wettbewerbs.

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33 ?1928 ———— Wirtschaftlichkeit der Junkers-Flugzeuge.

34 1928 ———— Jahresleistung der Junkers-Flugzeuge 1927.

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39 1928 ———— Die Junkerswerke in Dessau.

39a ?1929 ———— Schädlings-Bekämpfung.

40, 41 1929 ———— Ten Years of All-Metal Construction. (2 *copies.*)

42 1930 ———— Musterbezeichnungstabelle für Junkers-Flugzeuge.

43 1930 ———— Die Kühlung des Flugmotors in Vergangenheit, Gegenwart und Zukunft.

44 1930 ———— David and Goliath—a Contrast. (Junkers A-50 and G.38.)

45 1930 COLLINS, F. T. Metal Aircraft Construction: the Work of Junkers.

46 1930 (L'AERONAUTIQUE). Promenade à travers le Quadrimoteur Junkers G.38.

47 1930 JUNKERS A-G. Verzeichnis der Junkers-Literatur.

48, 49 1930 ———— The Junkers Heavy-Oil Aero Engine. (2 *copies.*)

50 1930 DAVIES, Dr. S. J. Opposed Piston Heavy-Oil Engines.

51 ?1931 JUNKERS A-G. Was muss die Flugzeugbesatzung vom Rohölflugmotor wissen?

52 1931 ———— Aerial Freight Service in New Guinea.

53, 54 1932 BANKS, CHAS. A. Air Transportation of Gold Dredges in New Guinea.

55 1932 BRUNS, WALTHER, BLENK, H., and Others. Luftfahrzeuge als Hilfsmittel in der Polarforschung. Die deutsche Untersuchung des Unfalls bei Meopham (England).

56 1932 TROST, H. R. Air Transport and Mining.

57 1933 JUNKERS A-G. A 17-passenger 169 m.p.h. Monoplane (Ju.52/3m.).

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59 1933 ———— Die aerodynamischen Grundlagen der Tragschraube.

60, 61 1934 ———— Schnellflug. (2 *copies.*)

62 1934 ———— Warum Drehflügel?

63 ?1934 LEICHTBAU, G.m.b.H. Stahl- und Glieder-Bau.
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(Aeronautical Research Committee Reports and Memoranda are in special Section AA; no list is given, as official index is available in Library.)

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1 *Daniel Guggenheim Fund.* (See Box Files Y.22 and Y.23.)
2 *Smithsonian Institution.* (See Box Files Y.30.i and Y.30.ii; also the following bound volumes of pamphlets:—
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Forest Products Research Board: PG.8. (And File Case, Section G.e.G.)
Committee on Mechanical Testing of Timber: PG.8.
Springs Research Committee: PG.9.
Gas Cylinders Research Committee. PG.9.
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II. Experiments with Dynamometer Hubs.
No. 20. I. Further Tests on Wing Profiles.
II. Measurement of the Pressure on Tail Planes.
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No. 28. Slotted Wings. (Tests made at Göttingen and at Vienna.)
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No. 31. Theoretical Considerations on the Problem of the Helicopter.

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Series III. Complete with Index.
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Air Estimates: Box File Y.20.i.
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2 R.A.F. General Duties Branch. (Candidates for Commissions.) Y.27.i.
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27 R.A.F. General Information. Y.27.i.
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38 Orfordness Rotating Wireless Beacon. (PM.2.)
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121 Regulations for Admission to the R.A.F. College, Cranwell. (Y.27.i.)
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359 B.R.2 Aero Engine. (EE.a.3.)
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595 Rigging Notes. D.H.9a. (PB.1.)
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817 Kite-Balloon Winch Manual. (C.c.2.)
826 Regulations for Civilian Employees at Air Ministry Establishments. (PD.3.)
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882 Lion Series 11B Aero Engine. (EE.a.31, 32, 44.)
904 R.A.F. General Duties Branch (Appointment of University Candidates). (Y.27.i.)
905 F.5 Boat Seaplane, Rigging Notes. (PB.1.)
913 Universal Camera Mounting. (PL.2.)
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949 The 12-cylinder Liberty Aero Engine. (EE.a.29 and 30.)
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1081 The R.A.F. Pocket-Book. 1924, '28 and '32 Eds. (S.b.1, 2, 3.)
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1224 Camera, Air, Type F.8. (L.j.13.)
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1275 General Instrument Equipment for Aircraft. (BB.f.1.)
1278 Jupiter Series VI Aero Engine. (EE.a.24.)
1287 Lynx IV Aero Engine. 1927 and '35 Eds. (EE.a.39 and 40.)
1299 Gamecock Aeroplane. (B.a.4.)
1317 Siskin IIIa Aeroplane. (B.a.5.)
1318 The Hyderabad Aircraft. (B.a.6.)
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1342 Lion Aero Engine (Series XIa). (EE.a.35.)
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I. Effect of Outline and Washout of Camber on the Aerodynamic Efficiency.
App. I.—Determination of Spindle Correction.
App. II.—Accuracy of Profile of Model Aerofoil Aeronautical Test Reports:—
1. Balance Portion for the Rudder of the F.3 Flying Boat.
2. Macdonald Aerofoils.
3. Rudder Balance for F.3 Flying Boat.
Bulletin No. 3. 1922. (Section 12.) By J. H. Parkin, H.C. Crane and J. S. A. MacAllister: Wind Tip Research.
II.—Warped Tips.
III.—Pin Tips.
IV.—Blade Tips.
(The remaining sections of Bulletin 3 are of non-Aeronautical interest.)
Bulletin No. 4. 1924. (Section No. 1.) By J. H. Parkin, H. C. Crane, J. S. E. MacAllister and E. V. Ahara.
Thick Aerofoils; Downwash; Grooved Aerofoil; End Spindle Corrections in Wind Channel Experiments; Investigation into the Effect of certain Variations in the Leading Portion of a Thick Aerofoil; Centre of Pressure Determination in Wind Channel Experiments.
(Section No. 11). By L. B. Stewart.
Certain Useful Forms for the Azimuth Formula.
Bulletin No. 5. 1925. (Papers of general Engineering and Metallurgical Interest.)
Bulletin No. 6. 1926. (Sections 12 and 13). By E. A. Allcut: Some Tests on a Two-Stroke Cycle Oil Engine. The Influence of Speed on Engine Performance.
Bulletin No. 7. 1927. (Section 1.) By J. H. Parkin, J. E. B. Shortt, C. G. Heard and J. G. Cade.
The New Aerodynamic Laboratory of the University of Toronto.
Research on Channel Wall Interference.
Pressure Distribution over U.S.A. 27 Aerofoil with Sqaure Wing Tips.
Pressure Distribution over Göttingen Aerofoil with Square Wing Tips.
Biplane Investigation.
(Section 7.) By A. E. Allcut.
Further Tests on a Two-Stroke Cycle Oil Engine.
Bulletin No. 8. 1928. (Section 9.) By J. H. Parkin, G. J. Klein, G. L. Roberts and W. H. Coates.
Airflow about Wing Tips.
International Trials.
The Interference between the Body and Wings of Aircraft.
Undercarriage Resistance.
(Sections 10 and 11.) By A. E. Allcut.
The Influence of Various Factors on the Power and Economy of a Gasoline Engine.
The Uniflow Steam Engine.
(Section 16.) By C. R. Young and W. B. Dunbar.
Permissible Stresses on Rivets in Tension.
Bulletin No. 9. 1922. (Section 8.) By E. A. Allcut.
The Distribution of Fuel in Multi-Cylinder Gasoline Engines.
(Section 10.) By T. R. Loudon.
Riveted Tension Members.
Net Section of Riveted Tension Members.

Note.—From this point, instead of collective Bulletins, the papers are issued singly, numbered from 140 onwards, as under:—

No. 140. Further Tests on the Heat Output of Concealed Radiators. By E. A. Allcut.
No. 141. Pressure Measurements as affected by the Location of the Piezometer Connection. By R. W. Angus, R. Taylor and C. G. Heard.
No. 142. Flow of Water through sudden Contractions and Enlargements, and Friction Loss in 2-inch Brass Pipe. By R. W. Angus.
No. 143. The Relative Rigidity of Welded and Riveted Connections. By C. R. Young and K. B. Jackson.
No. 144. (Missing.)
No. 145. Observed Soil Pressures on the deep Sewers of the North Toronto System. By C. R. Young and W. B. Dunbar.
No. 146. Old Forts in Upper Canada. By Fritz G. M. Winter and E. R. Arthur.
No. 147. The Influence of Cupels on Silver Loss. By J. T. King.

No. 148. Horizontal Thrusts for Two-Hinged Arches of Various Forms. By C. R. Young and M. W. Huggins.
No. 149. Heat Insulation as applied to Buildings and Structures. By E. A. Allcut and F. G. Ewens.
No. 150. Model Tests on Spillways in the Power Dam at Abitibi Canyon. By Robert W. Angus and J. B. Bryce.
No. 151. An Investigation of the Chlorination of Spruce Wood and of the resulting Chlorolignin. By G. V. Jansen and J. W. Bain.
No. 152. Water Hammer in Pipes, including those supplied by Centrifugal Pumps. (Graphical Treatment.) By R. W. Angus.
No. 153. St. Andrew's Church, Niagara-on-the-Lake. By E. R. Arthur.
No. 154. An Automatic Frequency Regulator. By H. W. Price and C. Kent Duff.
No. 155. Induced Asymmetry and Optical Resolution of 2-Phenylpyridine Derivatives. By J. G. Breckenridge and O. C. Smith.
No. 156. Transformer Leakage Inductance. By V. G. Smith.
No. 157. Action of Valves in Pipes (with Appendix). By Robert W. Angus.
No. 158. The Physical Structure of Heat Insulating Materials. (Air Infiltration.) By E. A. Allcut.
No. 159. The Rôle of Copper in the Deterioration of Rubber. By R. R. McLaughlin and G. P. Beal.

UC.3. **ENGINEERING INSTITUTE OF CANADA.**

Aeronautical Reprints: Nos. 1-9.

No. 1. *July* 1931.

Aerial Cameras and Photography. Flt.-Lt. J. R. Cairns.
Some Problems connected with Fluid Motion. J. J. Green.
Communication on Civil Airways in Canada. Lt.-Col. W. Arthur Steel.

No. 2. *December* 1931.

General Principles of Air Transportation. A. F. Ingram.
Recent Air Mail Development in South America. R. A. Logan.
Type Testing of Aircraft. F/O. A. L. James.
Aeronautics as a Branch of the Engineering Profession. Sqd. Ldr. Alan Ferrier.
Aviation in Canada and the National Research Laboratories. J. H. Parkin.
The Design and Construction of Metal Hulls for Boat Seaplanes. R. J. Moffett.

No. 3. *August* 1932.

Petroleum Testing. R. K. Stratford.
The Installation of Radial Air-Cooled Engines. A. H. Marshall.
Aircraft Instruments. R. H. Field and S. J. Murphy.

No. 4. *April* 1934.

Relations of Aeronautical Research to General Engineering. Sqd. Ldr. A. Ferrier.
Mapping from Aerial Photographs. A. E. Simpson.

No. 5. *February* 1935.

Contribution of the Aeroplane to Canadian Industrial Development. W. S. Burchall.
The Rationalisation of Load Factors for Aeroplane Wings. C. W. Crosland.
Testing of Aircraft Fuels. M. S. Kuhring.

No. 6. *December* 1935.

Streamlining. J. J. Green.
Trans-Atlantic Air Transport. J. H. Parkin.
Geological Mapping with Aeroplane Assistance. F. J. Alcock.

No. 7. *December* 1936.

The World's Airways System. J. A. Wilson.
High Altitude or Stratosphere Flying. Grp. Capt. E. W. Stedman.
Welding of Light-Walled Tubing. R. J. Anderson.
Trends in Aviation Lighting in the United States. Dr. F. C. Breckenridge.

No. 8. *August* 1937.

North Atlantic Air Service, London-Montreal. J. H. Parkin.

No. 9. *November* 1938.

The Development of Aviation in Canada. J. A. Wilson.
The Fatigue of Metals. G. S. Farnham.
Synthetic Plastics in Aircraft Construction. C. Y. Hopkins.
Canadian Air Transportation. G. A. Thompson.
Aircraft Engine Selection and Installation. M. S. Kuhring.
Simplified Performance Calculations for Aeroplanes. Elizabeth M. G. MacGill.

D. **CZECH.**

1. *Institute of Military Aviation Studies, Prague. (Vojensky Letecky Ustav Studijni v Praze.)* Reports.

Note.—These Reports are in Czech, with a brief summary either in French or in English, as indicated by the alternative title; for convenience, only the latter is given here.

No. 1. Mouvement de l'Air aux différents Niveaux de la Haute Atmosphère du Territoire de la République Tchécoslovaque. By Dr. V. Hlavác. 1927.
No. 2. A Study of the Relative Efficiency of Horizontal Flights and of the Mutual Adaptation of the Principal Parts of the Airplane. By Dr. V. Friedrich. 1927.
No. 3. Le Vol en Ballon Libre. By K. Chury. 1927.
No. 4. (Missing.)
No. 5. La Nomographie. By Dr. M. Hampl. 1928.
No. 6. Poutre Uniformément Chargé avec une Partie à Faux et Comprimé par des Forces Longitudinales entre les Appuis. By Prof. A. Van der Vliet.
No. 7. I. Résultats des Sondages aérologiques en 1926; II. Résumé des Résultats du Pilotage en 1926. By Dr. J. M. Mohr.
No. 8. Remarques sur le Calcul des Efforts dans l'Avion. By Prof. A. van der Vliet. 1928.

No. 9. About the Subjective Appearance of the Horizon-Line and Earth-Surface during Flights at High Altitudes; a Contribution to the Myosensoric Function of the Eye-Muscles. By Dr. G. Schubert. 1929. (IN ENGLISH, with summary in Czech.)
No. 10. Continuous Flow round Streamline Bodies with Potential of Velocity. Part I. By Prof. A. Van der Vliet. 1929.
No. 11. Ditto. Parts II and III.
No. 12. Ditto. Parts IV and V.
No. 13. Installations d'Eclairage pour la Navigation Aérienne de Nuit. By J. Karez. 1930.
No. 14. Le Développement des Appareils pour la Photographie Aérienne. By Dr. V. Chytry. 1931.
No. 15. Remarque sur le Calcul des Efforts dans l'Avion. By Prof. A. van der Vliet. 1931.
No. 16. Contribution à la Théorie et aux Essais des Profils de Mâts. By V. Smolar. 1931.
No. 17. Les Lois de la Similitude et Méthodes Expérimentales en Aérodynamique. By Dr. Emanuel Hof. 1931.
No. 18. Détermination de la Température de l'Air pendant les Essais en Vol. By V. Smolar. 1932.
No. 19. Laboratoire Aérodynamique de l'Institut Militaire des Recherches Aéronautiques. By Dr. Emanuel Hof. 1932.

E. **DUTCH.**

1 *Rijks-Studiedienst voor de Luchtvaart, Amsterdam:* Verslagen en Verhandelingen. (Reports in Dutch, each preceded by a brief summary in French, English and German. Titles of Reports are here given in English.)

Vol. I: 1921.
A.12. The Wind Channel of the "Rijks-Studiedienst voor de Luchtvaart."
A.7. Experiments on the effect of heating the upper wing surface on the lift and drag forces.
A.14. Preliminary experiments on the effect of the method of suspending the Model in aerodynamic measurements on the results. (i.e., How results are affected by the method of suspension.)
A.19. Experiments on a model of the Fokker F.II monoplane.
A.26. A Study of the Flow round a Streamline Strut.
A.10. Experiments on Pitot tubes.
A.20. Experiments on the effect of an angle between a Pitot tube and the direction of the Wind.
A.24. Experiments on a number of Wind-vanes.
B.3. Experiments with a six-cylinder 185 h.p. Open-B.M.W. Engine.
M.17A. On the Fatigue Resistance of Duralumin.
M.40A. Tests on the Strength of Fuselages, composed of seamless steel pipes, joined by autogenous Welding.
Vol. II: 1923.
A.51. Experiments with a device shortening the landing run and glide of an Aeroplane.
A.29. Experiments on the influence on the aerodynamic properties of cutting away part of the Leading Edge of a Fokker F.III wing.
A.20. Floating experiments (i.e., tank tests) made with a model of the Commercial Aeroplane Type Fokker F.III (with object of finding out how long a landplane would float if obliged to descend on the water).
A.64. Experiments on the resistance of Aeroplane Wheels and Radiators.
A.42. Influence of a deviation from the mean position on the readings of Airspeed Indicators.
A.48. Unstable Oscillations of a Wing-Aileron System.
Vol. III: 1925.
A.33. Experiments on the Pressure Distribution on the Fuselage of an Aeroplane Model.
A.58. Nomogram for the correction of incidence and drag of model Aerofoils tested in an air stream of finite dimensions.
A.77. Experiment on the pressure-drop in an air current caused by Metal Gauze.
A.96. Preliminary investigation into the influence of a rotating Cylinder in a Wing-Section.
M.14A. Experiments on the protection against humidity of wooden aeroplane parts by means of protective layers of Oil Varnish.
V.79. Photographic time-studies of aeroplane paths. (i.e., determination of performance by means of cinematographic apparatus and stop-watch.)
A.92. Experiments on the cooling power of two different radiators for the Fokker C.IV aeroplane.
(Vols. IV-VII missing.)
Vol. VIII: 1939.
A.544. The technical importance of large Wind Tunnels.
A.588. A Problem of Probability. (Estimation of probability of engine failure.)
V.834. The correction of the indication of a Thermometer placed in an air current.
V.1032. Determination of the speed of an Airplane by measuring the impact-pressure using a suspended static head.
S.82. The Torsion of Members having solid oblong Sections.
A.635. Diagram for the determination of the Critical Velocity of a Body towed by an Aeroplane.
V.737. The influence of the mobility in the liquid-containers of an Airplane on the elevator curves.
V.1165. The calibration of Airspeed Indicators for Airplanes and the reduction of their indication to real airspeed.
A.730. The correction of angle of incidence and resistance of a prismatic Aerofoil of finite span to those for the Aerofoil of infinite span.
A.557. The Influence of Wing-Warping on the Drag.
A.589. The Wall Interference for a Propeller in a mixed Wind Tunnel.

A.649. The motion of an oscillating System with one degree of freedom under the action of an arbitrary external force.

A.676. Comparison of the measured and calculated Load Distribution for a tapered Wing.

S.100. A Method to compare Flight Conditions for Aeroplanes (n-q diagram).

S.156. The torsional center of Beams, loaded by Shearing Forces.

F. FRENCH (& FRENCH-SPEAKING COUNTRIES)

1 *Chambre Syndicale des Industries Aéronautiques.*

Bulletin:—

Mai-Juin, 1927. Influence du Vent sur les Bâtiments. By M. Coupard.

Théorie et Tracés des Profils d'Ailes Sustentatrices (suite).

Mai-Juin, 1930. Tracés de Profils d'Ailes théoriques.

4 articles on light metal alloys.

Juillet-Août, 1930. L'Avion de Tourisme. By Ch. Treillard.

L'Avion de Tourisme BFW-23B.

Détermination de l'Amortissement d'un Matériau aux Essais de Torsion. By W. Knackstedt.

La Vie Aéronautique internationale. (Principaux voyages français en 1929.)

Septembre-Oct. 1930. Le XIIe Salon International de l'Aviation.

Le Cinquième Congrès International de la Navigation Aérienne.

Mars-Avril, 1931. Les Avions et Hydravions du XIIe Salon de l'Aéronautique (suite).

L'Aviation Commerciale aux Etats-Unis. By R. C. Wood.

Statistique comparative des accidents de l'Aeronautique aux Etats-Unis.

Les termes commerciaux et internationaux et leurs nouvelles définitions en France.

Juillet-Août, 1931. L'Aile à Fente.

Distribution de la pression de l'Eau sur un Hydravion à deux Flotteurs.

Les Abaques à transparent orienté ou tournant.

Septembre-Oct., 1931. Le Congrès National d'Aéronautique Coloniale.

L'Ecole Spéciale de Travaux Aéronautiques.

Les Abaques à transparent orienté ou tournant (suite).

2 *Institut Aérotechnique de l'Université de Paris.*

Bulletin. Nos. 1-3, in bound volume. 1911.

3 *Ministère de l'Air: Publications Scientifiques et Techniques.*

No. 1. Recherches théoriques sur le rendement et les conditions de réalisation des Systèmes motopropulseurs à réaction. By Maurice Roy.

No. 2. Recherches sur l'Hydrodynamique des Liquides visqueux. By A. Gay.

No. 3. Etude des Ecoulements irrotationnels dans l'Espace à trois dimensions. By A. Alayrac.

No. 4. Méthode géométrique de tracés de profils d'Ailes et de Corps fuselés; Essais sur la Viscosité en Mécanique des Fluides. By Maurice Girault.

No. 5. Soufflerie aérodynamique à dynamomètres électrométriques du Service des Recherches de l'Aéronautique. P. Rebuffet.

No. 6. Déviations radiogoniométriques à bord d'avion. E. Fromy.

No. 7. Etudes sur les constituants des Essences: Contribution à l'étude Physicochimique des Carbures cyclaniques. Godchot and Mlle. G. Cauquil.

No. 8. Recherches expérimentales sur les Ailes monoplanes. E. Carafoli.

No. 9. Etude des trajectories et des qualités aérodynamiques d'un Avion par l'emploi d'un Appareil cinématographique de bord. A. Magnan.

No. 10. Application des Méthodes interférentielles à l'étude de l'écoulement des gaz aux grandes Vitesses. R. Tremblot.

No. 11. Etude de la combustion des Mélanges gazeux. R. Duchesne.

No. 12. Sur la Distribution des Vitesses aérodynamiques autour d'un Avion en Vol. A. Magnan.

No. 13. Etude des écoulements irrotationnels dans l'espace à trois dimensions. A. Alayrac. (Suite de No. 3.)

No. 14. Méthodes d'appréciation des Lubrifiants. J. Damian.

No. 15. Etude de la Déformation des Hélices. Ch. Ledoux.

No. 16. Recherches sur le Mouvement d'un Fluide pesant dans un plan vertical. H. Poncin.

No. 17. Etude sur la transmission de la chaleur à l'Eau de Refroidissement dans un Moteur d'Aviation. Application à la Comparaison des Carburants. Mesures sur la Détonation. N. Champsaur.

No. 18. Sur les Cavitations de forme permanente. H. Poncin.

No. 19. Sur l'Oxydation électrochimique et la protection du Fer et des Duralumins dans les Solutions Salines aérées. E. Herzog.

No. 20. Etude des alliages magnésium-aluminium-cuivre, riches en magnésium. Contribution à l'Etude des Propriétés de Fonderie des Métaux et Alliages. P. Bastien.

No. 21. Application de l'effet Raman et de l'Absorption ultra-violette à l'identification des Carbures d'Hydrogène. A. Andant.

No. 22. Etat actuel des Recherches expérimentales sur les Anneaux de Tourbillons dans les Gaz. Contribution à l'Etude expérimentale des Phénomènes aérodynamiques aux faibles vitesses. Ch. Sadron.

No. 23. Contribution à l'Etude de la Corrosion du Fer. Potentiels du Fer et des constituents de l'Acier dans les divers milieux: passivité, activité. J. Aubert.

No. 24. Prévision de l'action d'un Vent dont la direction varie rapidement, application à l'effet Katzmayr et à l'autorotation. Obtention des Aérogrammes par Réfringence. Modification du Sillage des Corps. (I.) A. Lafay.

No. 25. Recherches expérimentales de Marey sur le Mouvement dans l'Air et dans l'Eau. P. Noguès.

No. 26. Tourbillons donnés par les Jets de très petite vitesse (Currentilignes). H. Bouasse.

No. 27. Contribution à l'étude de la Viscosité et de la Congélation des Huiles. M. Bourdiol.

No. 28. Etude des Flux d'Epuration et de Protection du Magnésium et de ses Alliages pendant leur Fusion dans les Creusets et leur Coulée dans les Moules. M. Hardouin.

No. 29. Sur le Calcul du Potentiel des Vitesses en Hydrodynamique. F. Vasilesco.

No. 30. Annales de Photographie Aérienne. (Tome Premier, 1931-32.) H. Roussilhe (Chef du Service de Photographie Aérienne au Ministère de l'Air).

No. 31. Mesure de l'Etanchéité intérieure des Moteurs à Explosion. Etude du Gommage. N. Champsaur.

No. 32. La Fonderie du Magnésium. A. Caillon.

No. 33. Recherches sur l'Etalement de l'Huile de Ricin et de divers Glycérides à la Surface de l'Eau. Ch. Bouhet and R. Lafont.

No. 34. Quelques applications des Spectres d'Absorption infra-rouges à l'étude des Constituants des Essences (Carbures à Noyaux). J. Lecomte and P. Lambert.

No. 35. Sur les petits mouvements d'un Système infini de Tourbillons autour d'une position d'équilibre. G. Durand.

No. 36. Expériences sur le Refroidissement d'un corps par un courant d'air. P. Vernotte and E. Blouin.

No. 37. Les Assemblages de Bois. (Tome Premier.) M. Monnin.

No. 38. Mesures de Densités photographiques par la Méthode photoélectrique. G. A. Boutry.

No. 39. Recherches sur la Fatigue des Aciers. R. Cazaud.

No. 40. Contribution à l'étude du Vieillissement de l'Huile de Ricin. Madeleine Roy.

No. 41. Moments aérodynamiques de différentes Gouvernes. P. Rebuffet.

No. 42. Recherches sur le Capotage des Moteurs en étoile à refroidissement par l'air. M. Giqueaux.

No. 43. Recherches sur les Constituants des Pétroles et des Gasoils. E. Carrière and H. Bonnet.

No. 44. Etude sur les Essais d'Emboutissage des Métaux. H. Fournier.

No. 45. Contribution à l'Etude des Alliages ternaires. R. Paris.

No. 46. Contribution à l'étude du Graissage. Mesure du Coefficient de Frottement des Huiles de Graissage et de leurs Constituants. Applications. Madeleine Briault.

No. 47. Etude d'une méthode utilisant le Couplage entre deux Systèmes oscillants pour la détermination de la Résistance mécanique des Constructions et la mesure des Modules d'Elasticité. P. Le Rolland and P. Sorin.

No. 48. Utilisation des substances phosphorescentes en Aéronautique. Un appareil de mesure des très faibles Brillances. M. Roulleau.

No. 49. Recherches sur l'Oxydation des Carbures d'Hydrogène et ses rapports avec la Détonation dans les Moteurs. Mlle. S. Estradère.

No. 50. Sur les Propriétés magnéto-optiques des Liquides. Application à l'Analyse des Carbures d'Hydrogène. M. Schérer.

No. 51. Recherches sur l'Etalement des Composants de l'Huile de Ricin. Ch. Bouhet and P. Lamarche.

No. 52. L'étude et le contrôle des Huiles de Graissage par la mesure des Tensions interfaciales huile-eau. L. Leprince-Ringuet.

No. 53. Contribution à l'étude expérimentale du Biplan d'envergure infinie. (I.) H. Girerd.

No. 53 bis. Contribution à l'étude expérimentale du Biplan d'envergure infinie. (II. Album de Planches.) H. Girerd.

No. 54. Recherches sur la Vaporisation des Carbures d'Hydrogène et des Mélanges de Carbures. Max Schmitt.

No. 55. Recherches sur la Résistance des Fluides dans un Mouvement non permanent. Méthode des Profils virtuels. M. Luntz.

No. 56. Contribution à l'Etude expérimentale des interactions d'une Sonde et d'un Corps de révolution. J. G. Portes.

No. 57. Application des analogies électriques à la Solution de quelques Problèmes de l'Hydrodynamique. L. Malavard.

No. 58. Recherches sur la Résistance à la Fatigue des Aciers au Carbone. M. Ogée.

No. 59. Recherches sur l'Ecoulement et les Pertes de Charge à travers les Grilles et les Filtres à Mailles. J. Lemains.

No. 60. Perturbations provoquées dans le Mouvement d'un Fluide par des Variations de la Température. C. Woronetz.

No. 61. Etude de la Sensibilisation chromatique et de la Désensibilisation des Emulsions photographiques. A. Charriou.

No. 62. Etude de l'Oxydation par l'Anhydride permanganique des Hydrocarbures purs existants dans les Essences et autres Carburants: Corps intermédiaires formés; vitesse d'Oxydation; extension à l'étude des Mélanges. J. F. Durand and Lai Wai Hsun.

No. 63. Phénomènes thermiques provoqués par le Déplacement relatif d'un Solide dans un Fluide. E. Brun.

No. 64. Contribution à l'Étude de la Corrosion. Mlle N. Goldowski.

No. 65. Turbulence et Frottement turbulent: Théorie de Karman. Ch. Sadron.

No. 66. Contribution à l'étude des Hexanes et de quelques Carbures d'Hydrogène. A. Maman.

No. 67. Phénomènes dans les Fluides tournants. H. Bouasse.

No. 68. Contribution expérimentale à l'étude des Souffleries supersoniques. L. Santon.

No. 69. Détermination des Températures de Gaz pendant la Détente dans les Moteurs à Explosion. M. Donescu.

No. 70. Recherches sur l'Analyse thermique des Alliages ternaires. (Application aux Alliages magnésium-silicium-zinc riches en magnésium.) E. Elchardus.

No. 71. L'Hydrodynamique du Cylindre tournant. M. Luntz and P. Schwarz.

No. 72. Les Transpositions de Matériaux en Construction. H. Portier.

No. 73. Etude de l'Ecoulement de l'Air autour d'une Hélice. J. Valensi.

No. 74. Etude des Ecoulements irrotationnels dans l'Espace à trois dimensions. (Suite des Nos. 3 and 13.) A. Alayrac.

No. 75. Le Magnésium dans les Constructions Aéronautiques. R. de Fleury.

No. 76. Etude expérimentale sur la Stabilité transversale des Avions. E. Duchêne.

No. 77. Influence des Caractéristiques atmosphériques sur la Puissance des Moteurs à Explosion. M. Serruys and Tchang Te-Lou.

No. 78. Contribution à l'étude de l'Explosion des Mélanges hydrocarburés. Y. Laure.

No. 79. Balance aérodynamique permettant le Tracé continu des Polaires. Effets singuliers produits par de très légères modifications de Structure du Vent. Contribution expérimentale à l'Aérodynamique du Cylindre et à l'Étude du Phénomène de Magnus. A. Lafay.

No. 80. Recherches sur les Propriétés diélectriques du Caoutchouc. J. Granier.

No. 81. Les Constituants de la Rouille. A. Girard.

No. 82. L'état passif des Métaux. Etude de la passivité du Nickel. L. Colombier.

No. 83. Sur le Couple des Roulements à Billes. M. Delfosse.

No. 84. Recherche des Contraintes dans les Poutres de Hauteur variable. V. A. Nicolsky.

No. 85. Observations sur le Laminage des Alliages magnésium - aluminium. Mlle. L. Doussin and F. Fournier.

No. 86. Recherches sur les Cellules biplanes rigides d'Envergure infinie. M. Nénadovitch.

No. 87. Recherches sur l'influence de l'Angle d'Ouverture d'un Ajutage divergent sur l'Ecoulement à deux dimensions de l'Air à travers cet ajutage. J. Demontis.

No. 88. Enduits cellulosiques pour Toile d'Avions. J. Grard.

No. 89. Etude du Système antimoine-étain-zinc et contribution à l'étude des Antifrictions à base de Zinc. R. Blondel.

No. 90. Electromètre Plan-sphère à suspension bifilaire. F. Charron.

No. 91. Etude de la Susceptibilité corrosive des Métaux par la Méthode coloriscopique et par la Méthode des Eprouvettes minces. M. Prot and Mlle. N. Goldowski.

No. 92. L'écoulement des Fluides au voisinage des points singuliers des Obstacles. L. Sackmann.

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No. 5. Sul Calcolo delle Fusoliere a Traliccio. By Dr. C. Riparbelli.
No. 6. Il Bacino della Vasca Idrodinamica di Guidonia. By Prof. C. Cremona.
No. 7. Una caratteristca Trasformazione delle Equazioni dello Strato Limite nei Gas. By Prof. L. Crocco.
Nos. 8-9. Nuovi Sviluppi sul Meccanismo a Biella Madre e Bielletta e Questioni Dinamiche nei Motori Stellari. By Prof. Luigi Crocco.
No. 10. Introduzione di un nuovo e generale "Principio di Equivalenza" per lo Studio delle Strutture Elastiche. By Dr. Luigi Broglio.
No. 11. Carico Critico di Punta delle Aste Euleriane Semincastrate. By C. Riparbelli.
No. 12. Un nuovo Calcolo a torsiono per Strutture Alari. By Dr. Luigi Broglio.
No. 13. Il Laboratorio Aerodinamico di Guidonia. By Prof. Antonio Eula.
No. 14. Contributo alla Teoria delle Strutture Iperstatiche. Un Nuovo e Generale Procedimento il Calcolo. By Luigi Broglio.
No. 15. La Galleria Ultrasonora di Guidonia. By Antonio Ferri.
No. 16. Contributo alla Teoria del Solidi cavi a Parete sottile. Introduzione di un Nuovo e Generale Procedimento di Calcolo per le Ali a Cassone. (I Parte.)
No. 17. Alcuni Risultati sperimentali riguardanti Profili Alari provati alla Galleria Ultrasonora di Guidonia. By Dr. A. Ferri.
No. 18. Il Comportamenta del Giroscopio Direzionale Tipo Sperry in Virata. By R. Rosselli del Turco.

No. 19. Su alcuni Abachi utili nelle Prove al Banco e in Volo dei Motori con Compressore. By Dr. Pl.l Torre.
No. 20. Esperienze sistematiche sul Modello di Idrovolante Biscafo "G.I.S.6" in varie condizioni di Assetto e di Dislocamento, in relazione alla Distanza fra le Mezzerie degli Scafi. By Prof. C. Cremona.
No. 21. Considerazioni sulla Progettazione di Eliche per Apparecchi Veloci. By Dr. A. Ferri.
No. 22. Condizioni Fisiologiche del Volo ad Alta Quota. By Dr. R. Margaria.
No. 23. La Galleria Verticale per le Esperienze di Avvitamento. By Dr. A. Vannucci and Dr. V. Ciampolini.
No. 24. Una Bilancia Aerodinamica a 6 Componenti. By Dr. Antonio Eula.

4 *R. Politecnico di Torino* (*Laboratorio di Aeronautica*).
(For Publications up to No. 100, and No. 104, see Box File Y.28.)
No. 101. Sul moto rotazionale dei Gas. C. Possio. 1937.
No. 102. Recerche sperimentali sulle azioni aerodinamiche sopra l'Ala oscillante. P. Cicala. 1937.
No. 103. Freni per Automezzi. Attrito ed usura delle loro Guarnizioni. A. Castagna.
No. 105. Campi di Correnti ipersonora attorno a Solidi di Rivoluzione. C. Ferrari.
No. 106. Sulle condizioni di Vincolo (Anello d'Imposta) nelle Cupole sferiche a parete sottile. E. Lorenzelli.
No. 107. Sul moto non stationario di un' Ala di Allungamento finito. P. Cicala.
No. 108. Bilancie Aerodinamiche a sei Componenti. M. Panetti.
No. 109. L'Impianto per prove dei Motori in Condizioni Stratoferiche. A. Capetti. 1937.
No. 110. Sistemazioni elettriche per lo Studio sperimentale della Dinamica dei Fluidi. C. Ferrari.
No. 111. Ricerche particolari riguardo all'Impiego dell'Alcool etilico nei Motori veloci ad Iniezione ed a Carburazione. A. Capetti.
No. 112. Il Problema aerodinamico del Volo ad Ala battente. P. Cicala.
No. 113. Ricerche sperimentale sulle azioni aerodinamiche sopra l'Ala oscillante. P. Cicala.
No. 114. Ricerca grafica dei Coefficienti di Resistenza e di Momento idrodinamico di un Idroscivolante munito di Ala e Determinazione dei Calettamenti ottimi Ala-Scafo. E. Lorenzelli.
No. 115. Sulla Teoria della Turbolenza. C. Ferrari. 1938.
No. 116. Sulla Correzione di Quota per gli Anemometri a Turbo di Pitot. L. Elia. 1938.
No. 117. L'Azione aerodinamica su una Superficie portante in moto oscillatorio. C. Possio. 1938.
No. 118. Determinazione dell'Azione aerodinamica corrispondente alle piccole Oscillazioni del Velivolo. C. Possio. 1938.
No. 119. Sul Calcolo dell'Ala bilonghe-rone con Rivestimento resistente al Taglio. P. Cicala. 1939.
No. 120. Sul Sparo di fianco da bordo di un Aereo. C. Possio. 1939.
No. 121. Sul Moto non stazionario di una superficie portante. C. Possio. 1939.
No. 122. Sulla determinazione dei Coefficienti aerodinamici che interessano la Stabilità del Velivolo. C. Possio.
No. 123. Le Oscillazioni proprie di un Corpo rigido sostenuto elasticamente. P. Cicala.
No. 124. Sugli Orizzonti artificiali. L. Elia.
No. 125. Sulle Travi di Altezza variabile. P. Cicala.
No. 126. La Geometria delle Ruote dentate e le sue relazioni coi Problemi di Lavorazione, Lubrificazione e Resistenza. M. Panetti.
No. 127. L'Azione aerodinamica su di una Superficie portante in Moto Vario. C. Possio.
No. 128. Sulla Determinazione del Proietto di minima Resistenza d'Onda. C. Ferrari.
No. 129. Campo di Velocità ed Onde superficiali prodotte dall'Urto e dall'Aflondamento di un Corpo in un Fluido pesante con Superficie libera a Pressione costante. E. Lorenzelli.
No. 130. Sul Moto non stazionario di un Fluido compressible. C. Possio.

5 *R. Scuola Normale Superiore di Pisa.*
Annali.
Serie II, Vol. II, No. 2. 1933.
Propriétés des Fonctions Harmoniques dans un Domaine ouvert limité par des Surfaces à Courbure bornée. C. de la Vallée Poussin.
Geometria completa dei trasporti rigidi su una V_2. G. Andreoli.
Eine Frage über trigonometrische Polynome. E. Landau.
Sul Procedimento di Arrotondamento di Schwarz. A. Del Chiaro.
Sur une propriété des Fonctions Holomorphes. D. Pompeiu.
Sopra alcune questioni di Statica dei Sistemi continui. A. Signorini.
Carl Pirath.

J. POLISH.

1 *University Joseph Pilsudski, Warsaw.* (*Institute of Aviation Law.*)
Report. (In Polish only.)
1. Sprawozdanie z Inauguracji Prac Instytutu.
Lotnictwo w Zyciu Krajow Zamorskich. Prof. R. Rybarski.
(Bulletin inaugurating the publications of the Institute. "Aviation and the Colonial Problem," by Prof. R. Rybarski.) 1928.
2. Administracyjne Prawo Lotnicze. B. Wasiutynski. (Administrative Aerial Law.) 1939.

2 *Institut des Recherches de l'Aéronautique, Varsovie. (Instytut Badan Technicznych Lotnictwa.) Afterwards called: Institut Technique de l'Aéronautique. (Instytut Techniczny Lotnictwa.)*

Bulletins. (Side-by-side text in Polish and French; for convenience, titles are here given in French only.)

No. 6. 1931. 26 Sur la " coopération des Longerons dans les Ailes des Monoplans." M. T. Huber.

27 Le Freinage des Roues de l'Avion pendant l'Atterrissage. S. Neumark.

28 Adaptation du Carburant essence-alcool au Moteur Lorraine-Dietrich 450 CV. F. Peter (& Others).

29 Sur le Calcul du Moment aérodynamique pour les Ailes à Profil constant et à Contours et Dièdres différents. C. Bieneck.

30 De l'Eclairage de la Chambre obscure photographique. Marja Moraczewska. and W. Daniewski.

31 L'Influence de la grosseur du Grain de l'émulsion photographique sur la construction de l'Appareil photo-aérien. T. Gutkowski.

32 Sur la Mesure de la Hauteur des Avions pendant le Décollage. T. Gutkowski.

No. 7. 33 Recherches sur le Sapin provenant des montagnes de Worochta. Partie III. S. Kozanecki.

34 Mesures de la répartition des Pressions derrière l'Hélice. S. Grzeszcyk.

35 Remarques supplémentaires sur le Freinage des Roues de l'Avion pendant l'Atterrissage. S. Neumark.

36 Calcul du Train d'Atterrissage d'un Avion par la Méthode de Forces unitaires. F. Janik.

37 Assemblages par Rivets en Duralumin. Partie I. S. Weiss.

38 Sensibilisation des émulsions du Pays pour le Rouge et l'Infrarouge. Marja Moraczewska.

No. 8. 1932. 39 La Méthode analytique dans la Mécanique du Vol. S. Neumark.

40 Etudes expérimentales sur la Coopération des Longerons dans les Ailes en Porte à Faux. Z. Luczynski.

41 Etude sur la Résistance à la Flexion des Longerons en Bois. R. Bartel.

42 Calcul de la Longueur de Routement à l'Atterrissage de l'Avion, en tenant compte du Freinage des Roues. F. Janik.

43 Influence de la Masse des Roues sur l'Equilibre de l'Avion à l'Atterrissage. F. Janik.

37 (bis) Supplément à l'Article " Assemblages par Rivets en Duralumin " dans le Bulletin No. 7.

No. 9. 1932. 44 Etalonnage des Barographes. J. Pawlikowski.

45 Benzol d'Aviation dans les Carburants alcool-essence. B. Mielnikowa.

46 Calcul des Trains d'Atterrissage hyperstatiques. F. Janik.

47 Essais des Dynamos d'Aviation Type R.D.1. K. Jagoszewski.

No. 10. 1932. 48 Sur la Charge et la Stabilité du Train d'Atterrissage. F. Janik.

49 Recherches sur le Sapin provenant de Wisła. S. Kozanecki.

50 Sur les Coefficients d'Elasticité du Contreplaqué. A Grzedzielski.

51 Résultats de la III-e série d'essais sur la Propagation des Ondes intermédiaires et courtes. D. M. Sokolcow and J. Bylewski.

No. 11. 1933. 52 Assemblages par Rivets en Duralumin. Partie II. A. Grzedzielski.

53 Recherches sur le coefficient d'élasticité du Contreplaqué d'Aune. K. Wójcicki.

54 Sur les Efforts en Vol remorqué. F. Janik.

No. 12. 1923. 39 (bis) La Méthode analytique dans la Mécanique du Vol. S. Neumark. (Suite—Voir Bulletin No. 8.)

55 Assemblages par Rivets en Duralumin. Partie III. A. Grzedzielski.

56 Flexion des Tubes à Parois Minces à Section Circulaire. I. Walter.

No. 13. 1934. 57 Sur un Cas particulier de coopération des Longerons d'Ailes. A. Grzedzielski.

58 Essais d'Oxydabilité comme critères des plus importants au choix des Huiles Lubrifiantes pour les Moteurs à combustion interne. B. Mielnikowa and J. Dziewonski.

59 Sur la mesure du Décollage à l'aide de l'appareil de DVL-Zeiss. T. Gutkowski.

60 Conditions d'Equilibre et de Stabilité Longitudinale du Monoplan. W. Wolibner.

No. 14. 1934. 61 La Résistance des Longerons de Pin fléchis. J. Naleszkiewicz.

No. 15. 1934. 62 Calcul des Fuselages en Treillis. A. Grzedzielski (& Others).

63 Recherches sur le Sapin provenant de Wisła. Terrain d'Essais No. 2. S. Kozanecki.

No. 16. 1935. 64 L'Application des Equations intégrales à la Statique des Avions. A. Grzedzielski and R. Seredynski.

65 Vibrations de Torsion des Vilebrequins. K. Wolski.

66 L'Influence de la Convergence des Longerons sur la Coopération. I. Walter.

67 Etude sur l'Essence d'Aviation polonaise. B. Mielnikowa and J. Tuszynski.

No. 17. 1935. 68 Examples de Remplacement d'une Diagonale dans le Treillis du Fuselage par un Système de Barres. A. Grzedzielski and E. Kosko.

69 Calcul d'une Aile monolongeron. W. Billewicz and A. Grzedzielski.

No. 18. 1935. 70 A propos des Méthodes de Mesures des Déformations du Contre-Plaqué de Bouleau à Bakélite travaillant comme Revêtement portant dans les Constructions Aéronautiques. R. Kurowski.
71 L'Appréciation des Enduits d'Aviation. U. Debska and B. Mielnikowa.
72 Les Efforts d'un Avion en Air agité. F. Janik.
No. 19. 1936. 73 Effet du Vent sur le Câble de Retenue d'un Ballon Captif. S. Neumark.
74 Essais de Fatigue du Bois. S. Kozanecki.
No. 20. 1936. 75 Les Coefficients d'Elasticité des Contreplaqués d'Aviation de Bouleau à Bakélite et les Méthodes de la Détermination de ses Coefficients. R. Kurowski.
76 Recherches sur le Plissement des Parois des Profils laminés. I. Walter.
(*Note.*—The latter is in Polish, with only résumé in French.)
No. 71. 1937. 77 Sur la Rigidité de la Tôle flambée. A. Grzedzielski and W. Billewicz.
78 Mesures des Efforts résultants dans les Clefs. Méthode élasto-optique. Z. Gubrynowicz.
79 Méthodes et Résultats des Recherches sur les Vernis à la Nitrocellulose. H. Patkowska and A. Surminski.
80 Méthode de Mesure du Coefficient d'un Ecran coloré. T. Gutkowski.

K. RUSSIAN.

1 *Institut Aérodynamique de Koutchino.*
Bulletins. Nos. 1/2, 3, 4, 5. (Bound Volumes; 1906-14.) Text in French.

2 *Heavy Industries Centre* (*Aero Engines*). (*Edited by P. I. Baranov.*)
(Text in Russian only; a few numbers have summaries in English and/or German, as indicated below. For convenience, titles are given in English.)
No. 1. 1936. Collective Volume, containing the following articles:—
Influence of Cooling Temperature on the Output of a Diesel Engine. A. N. Rakhmanovitch.
Calculations in connection with parts of High - Speed Two - Stroke Engines. A. S. K. Orlin.
Experimental determination of the Heat Transfer from the grooved surface of an Air-cooled Cylinder. L. G. Sheremetev.
Tolerances in the Production of Crankshafts of Aircraft and Motor Car Diesel Engines. A. S. Kuprianov.
Inertia Forces in Propeller Blades. N. P. Lopukhov.
Effect on the dynamic behaviour of an Engine of the non-coincidence of the Centre of Gravity with the Axis of the Connecting Rod. I. Sh. Neyman.
No. 3. 1934. The Dynamics and Stress and Design Calculations of Aircraft Engines. Part II: Stress and Design Calculations. I. Sh. Neyman. (On Library shelves, ref.: EE.c.29.)
No. 4. 1933. Aircraft Engine Testing at Altitude Conditions. (Collective Volume, containing the following articles:—)
Description of Altitude Chamber. A. A. Rosenfeld. (Summary in English.)
Testing of an Aircraft Engine, Type Liberty II. A. Dobrinin and K. Minkner.
BMW VI Motor Testing in Altitude Chamber. K. Minkner and A. Rosenfeld.
No. 6. 1934. Investigation and Testing of the Packard Aircraft Diesel Engine. A. D. Charomski and L. M. Velinki. (Summary in English and German.)
No. 9. Calculation of the amount of Compressed Air required for the starting of a V-Type Aircraft Diesel Engine. I. S. Skridov.
The Vibrations of the Needle Valves of enclosed type Injectors of Diesel Engines. V. Natanzon.
Study of the closed-work Cycle of an Internal Combustion Engine. M. A. Khailov.
The Kinematics and Dynamics of an Engine without a Crankshaft. V. Natanzon. (In Oil Engines Section: Ref. EE.f.24.)
No. 11. A Study of the Effect of Additions on the Combustion of Air-Methane Mixtures under Pressure. N. Schmigelski and K. Chukaev.
No. 13. Theory of Blowers used in Aviation (centrifugal, turbocompressor and volumetric). V. I. Dmitrieski. (Summary in English and German.)
No. 14. The Effect of Variations in Temperature and Pressure of the indrawn Air upon the Performance of a Carburettor. M. M. Maslennikov and K. A. Rudski. (Summary in German.)
No. 16. Methods of correcting Cylindrical Gear Wheels with straight Teeth. (External Meshing.) A. N. Kaluzhnikov.
No. 17. The Working Cycle of a Diesel Aircraft Engine. A. D. Charomsky. (In Oil Engines Section: Ref. EE.f.23.)
No. 18. The Blowing of High-Speed Two-Cycle Engines. A. S. Orlin.
No. 19. Diagrams for use in calculating the performance of Aircraft Engines working at Altitude. M. M. Maslennikov.
No. 20. Tests of the "Körting" Oil Engine. L. V. Vasin.
The Dynamics of the Injection System of Diesel Engines. V. Natanzon.

3 *Central Aero-Hydrodynamical Institute of Professor Joukowsky.* (*C.A.H.I.*)
Transactions. Series: Nos. 1-283, incomplete. Text in Russian, most, but not all, having a summary in English. No list is given of these Transactions, as there is an Index placed at the end of the series. The following numbers are missing:—
20, 28, 31, 42, 48, 54, 64, 68, 77, 79, 81-85, 87, 88, 90, 92, 94-97, 100-102, 104, 105, 108-11, 113, 116, 124-26, 145, 150, 155, 165, 171, 180, 194,

196, 212, 214, 219-221, 225, 229, 230, 232, 240, 278, 280.

4 *Moscow Institute of Transport Engineers.*
Transactions. (Edited by Prof. Dzherzhinski.)
Vol. XIV. 1929. (Text in Russian; list of contents given also in French; articles dealing with railway questions.)
Vol. XV. 1930. (Text in Russian; list of contents given also in German; articles of general Mechanical interest.)

5 *Institute of Energetics.*
Transactions. (Edited by G. M. Krzhizhanovsky.)
No. 1. 1933. Text in Russian; list of contents given also in English; articles on Fuel Systems and Thermodynamics.

6 *Ukrainian Academy of Sciences.*
In Russian, with summary in English.
No. 20. On the Stability of Structures in Compression-Bending. By N. V. Kornoukhov. 1936.
No. 21. Strength of Wood under Repeated Loading. By F. P. Beliankin. 1936.
No. 33. Theory of Strength in Variable Loading. By S. V. Sörensen. 1938.
No. 34. The Influence of Asymmetrical Cycles of Lading and of the Concentration of Stresses on the Strength of Wood under Repeated Loads. By F. P. Beliankin. 1938.
No. 40. Frequency of Proper Vibrations of Rods and Frames and the Dynamic Criteria of their Stability. By V. G. Chudnovsky. 1939.

L. ASIATIC COUNTRIES.

1 *Academia Sinica (CHINA).*
The Academia Sinica and its National Research Institutes. 1931. (Text in English; includes a List of Publications, in English and Chinese.)

2 *Harbin Polytechnic Institute (CHINA).*
Journal and Transactions: Vol. 4, No. 1. (Text in Russian.)

3 *Institute of Physical and Chemical Research Tokyo (JAPAN).*
Reports: From No. 41 onwards. (Text usually in English; a few in German; no list is given of these Reports, as they are mainly of non-Aeronautical interest.)

4 *Tokyo Bunrika Daigaku (JAPAN).*
Science Reports. Series, from No. 1 onwards. (Text usually in German; mainly of non-aeronautical interest.)

5 *National Research Council, Tokyo (JAPAN).*
Japanese Journal of Engineering: Abstracts. 1936, 1937, 1938, 1939. (Text in English.)

6 *Aeronautical Research Institute, Tokyo University (Japan).*
Reports of the Aeronautical Research Institute, Tokyo Imperial University, Vols. 1-12.

*UU. NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. (U.S.A.)

a. Technical Notes: Complete Series from No. 1 onwards. (Bound Volumes.) Unbound duplicates may be borrowed, if available. Stencilled index lists may be consulted in the Library.

b. Technical Reports: Complete Series from No. 1 onwards. (Bound Volumes.) Unbound duplicates may be borrowed, if available. Printed catalogue (to January 1938) may be consulted in the Library.

c. Technical Memoranda. Odd numbers as under:—

No. 411. Determining the Velocity Distribution in the Boundary Layer of an Airfoil fitted with a Rotary Cylinder. B. G. van der Hegge Zijnen. (Report A.129 of Rijks-Studiedienst voor de Luchtvaart, Oct. 23, 1926.)

No. 458. Steel Spars. Brian L. Martin. ("The Gloster," Sept./Dec. 1927.)

No. 482. Ignition and Combustion Phenomena in Diesel Engines. F. Sass. Z.V.D.I., Sept. 10, 1927.)

No. 490. Structures of Thin Sheet Metal: their Design and Construction. H. Wagner.

No. 491. Propeller Problems. A. Betz. 1928. (From Z.A.M.M., Vol. VII, 1927.)

No. 511. On the Strength of Box Type Fuselages. J. Mathar. (W.G.L., Jahrbuch, 1928.)

No. 533. Handley Page Metal Construction. (Flight, May 9, 1929.)

No. 544. Airplane Drag. Carl Töpfer. (Die Luftwacht, Sept., 1929.)

No. 546. Structural Details of the Giant Dornier Seaplane "Do.X." C. Gustosa. (Rivista Aeronautica, Oct., 1929.)

Series from No. 869, as under:—

No. 869. The Conversion of Energy in a Radiator. By A. Weise. (From Hauptversammlung 1937 der Lilienthal-Gesellschaft.)

No. 870. Behaviour of a Plate Strip under Shear and Compressive Stresses Beyond the Buckling Limit. By A. Kromm and K. Marguerre. (From Luftfahrtforschung, Vol. 14, No. 12, December, 1937.)

No. 871. Performance of Rotating-Wing Aircraft. By K. Hohenemser. (From Ingenieur-Archiv, Vol. 8, December, 1937.)

No. 872. The Present Status of Airship Construction, especially of Airship-Framing Construction. By Hans Ebner. (From Z.F.M., Vol. 24, Nos. 11 and 12, June 6 and 28, 1933.)

No. 873. Experimental Study of Ignition by Hot Spot in Internal-Combustion Engines. By Max Serruys. (From Ministère de l'Air, P.Sc.T. No. 115.)

No. 874. Effect of Propeller Slipstream on Wing and Tail. By J. Stüper. (From Luftfahrtforschung, Vol. 15, April 6, 1938.)

No. 875. Heat-Stressed Structural Components in Combustion-Engine Design. By Otto Kraemer. (From Zeitschrift des V.D.I., Vol. 82, March 12, 1938.)

No. 876. Investigations on the Downwash behind a Tapered Wing with Fuselage and Propeller. By H. Muttray. (From Luftfahrtforschung, Vol. 15, March 20, 1938.)

No. 877. Wind-Tunnel Investigations of Flexural-Torsional Wing Flutter. By H. Voigt. (From Luftfahrtforschung, Vol. 14, September 20, 1937.)

No. 878. The Twisting of Thin-Walled, Stiffened Circular Cylinders. By E. Schapitz. (From Lilienthal Gesellschaft Jahrbuch, 1936.)

No. 879. Static Longitudinal Stability and Longitudinal Control of Autogiro Rotors. By M. Schrenk. (From Luftfahrtforschung, Vol. 15, July 6, 1938.)

No. 880. The Effective Width of Curved Sheet after Buckling. By W. A. Wenzek. (From Luftfahrtforschung, Vol. 15, July 6, 1938.)

No. 881. Application and Testing of Transparent Plastics Used in Aeroplane Construction. By K. Riechers and J. Olms. (From Luftwissen, Vol. V, June, 1938.)

No. 882. Modern Manufacturing Equipment of the Ernst Heinkel Airplane Works. By A. Thormann and H. Jockisch. (From Luftfahrtforschung, Vol. XV, January, 1938.)

No. 883. Distribution of Temperatures over an Airplane Wing with Reference to the Phenomena of Ice Formation. By Edmond Brun. (From Ministère de l'Air, P.Sc.T. No. 119.)

No. 884. Calculation of the Induced Efficiency of Heavily-loaded Propellers having an Infinite Number of Blades. By F. Lösch.

The Induced Efficiency of Optimum Propellers having a Finite Number of Blades. By K. N. Kramer.

Prospects of Propeller Drive for High Flying Speeds. By G. Bock and R. Nikodemus. (From Luftfahrtforschung, Vol. 15, July, 1938.)

No. 885. Meteorological-Physical Limitations of Icing in the Atmosphere. By W. Findeisen. (From Hauptversammlung der Lilienthal-Gesellschaft, October, 1938.)

No. 886. Theory of Two-Dimensional Potential Flow about Arbitrary Wing Sections. By H. Gebelein. (From Ingenieur-Archiv, Vol. IX, June, 1938.)

No. 887. Comparison of Theory with Experiment in the Phenomenon of Wing Flutter. By P. Cicala. (From Aerotecnica, Vol. XVIII, April, 1938.)

No. 888. Ice Formation on Wings. By L. Ritz. (From Hauptversammlung der Lilienthal-Gesellschaft, October, 1938.)

No. 889. Investigation of the Lift Distribution over the Separate Wings of a Biplane. By D. Küchemann. (Luftfahrtforschung, Vol. XV, October, 1938.)

No. 890. Experiments on a Slotted Wing. By P. Ruden. (From Jahrbuch der Luftfahrtforschung, 1937.)

No. 891. Theoretical and Experimental Study of Ignition Lag and Engine Knock. By Fritz A. F. Schmidt. (From V.D.I.-Forschungsheft 392.)

No. 892. Investigations and Tests in the Towing Basin at Guidonia. By C. Cremona. (From Hauptversammlung der Lilienthal-Gesellschaft, October, 1938.)

No. 893. Contribution to the Theory of the Heated Duct Radiator. By H. Winter. (Luftfahrtforschung, Vol. XV, October, 1938.)

No. 894. The Way to Increased Airplane Engine Power. By Eugen Vohrer. (From Luftwissen, Vol. 5, October 1938.)

No. 895. The Power of Aircraft Engines at Altitude. By Paolo Ragazzi. (From Hauptversammlung der Lilienthal-Gesellschaft, October, 1938.)

No. 896. The Drag of Airplane Radiators with Special Reference to Air Heating. (Comparison of Theory and Experiment.) By B. Göthert. (From Luftfahrtforschung, Jahbuch 1937.)

No. 898. The Limit of Stability of a Curved Plate Strip under Shear and Axial Stresses. By A. Kromm. (From Luftfahrtforschung, Vol. XV, October, 1938.)

No. 899. The Hydrodynamic Theory of Detonation. By Heinz Langweiler. (From Z.T.P., Vol. 19, No. 9, 1938.)

No. 900. The Effect of the Masses of the Controls on the Longitudinal Stability with Free Elevator. By Rudolph Schmidt. (From Luftfahrtforschung, Vol. XVI, January, 1939.)

No. 901. Investigations and Experiments in the Guidonia Supersonic Wind Tunnel. By Antonio Ferri.

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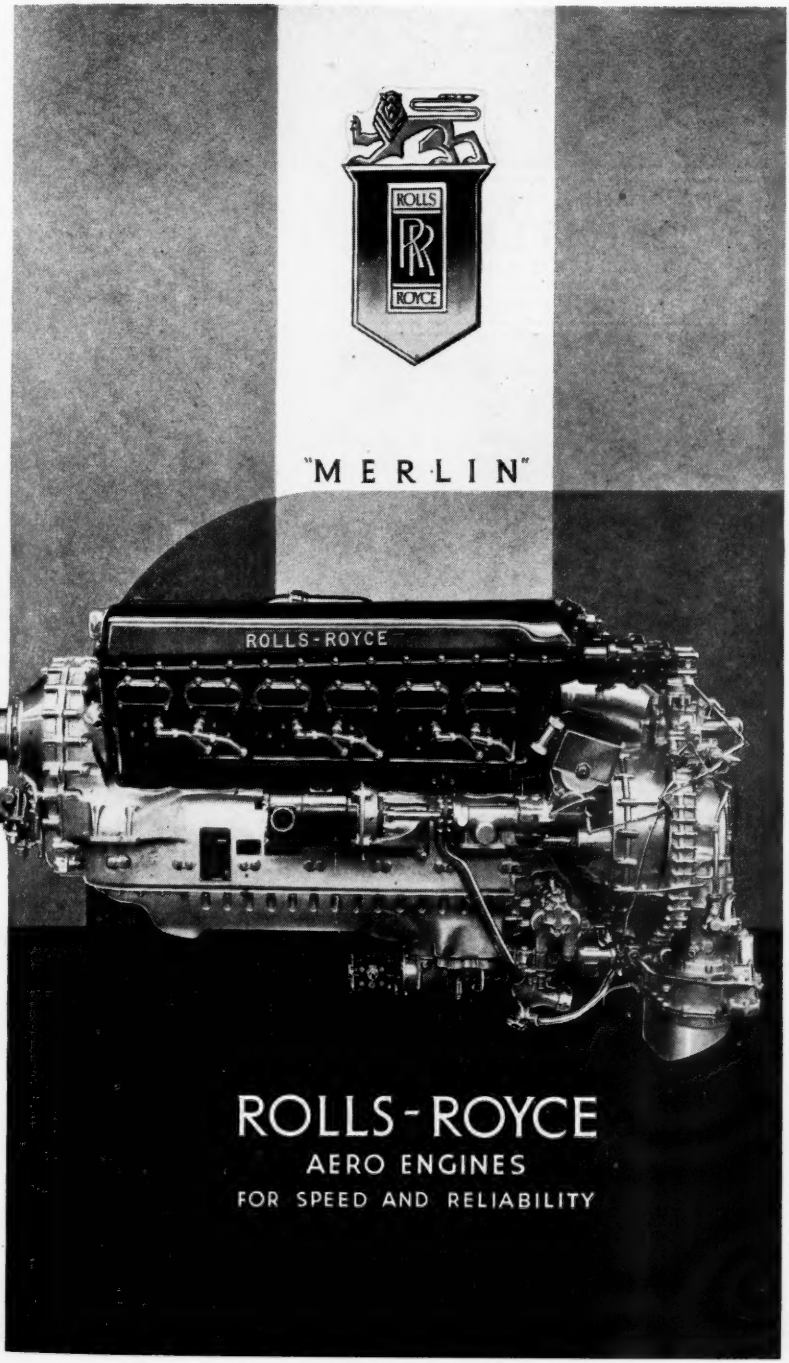
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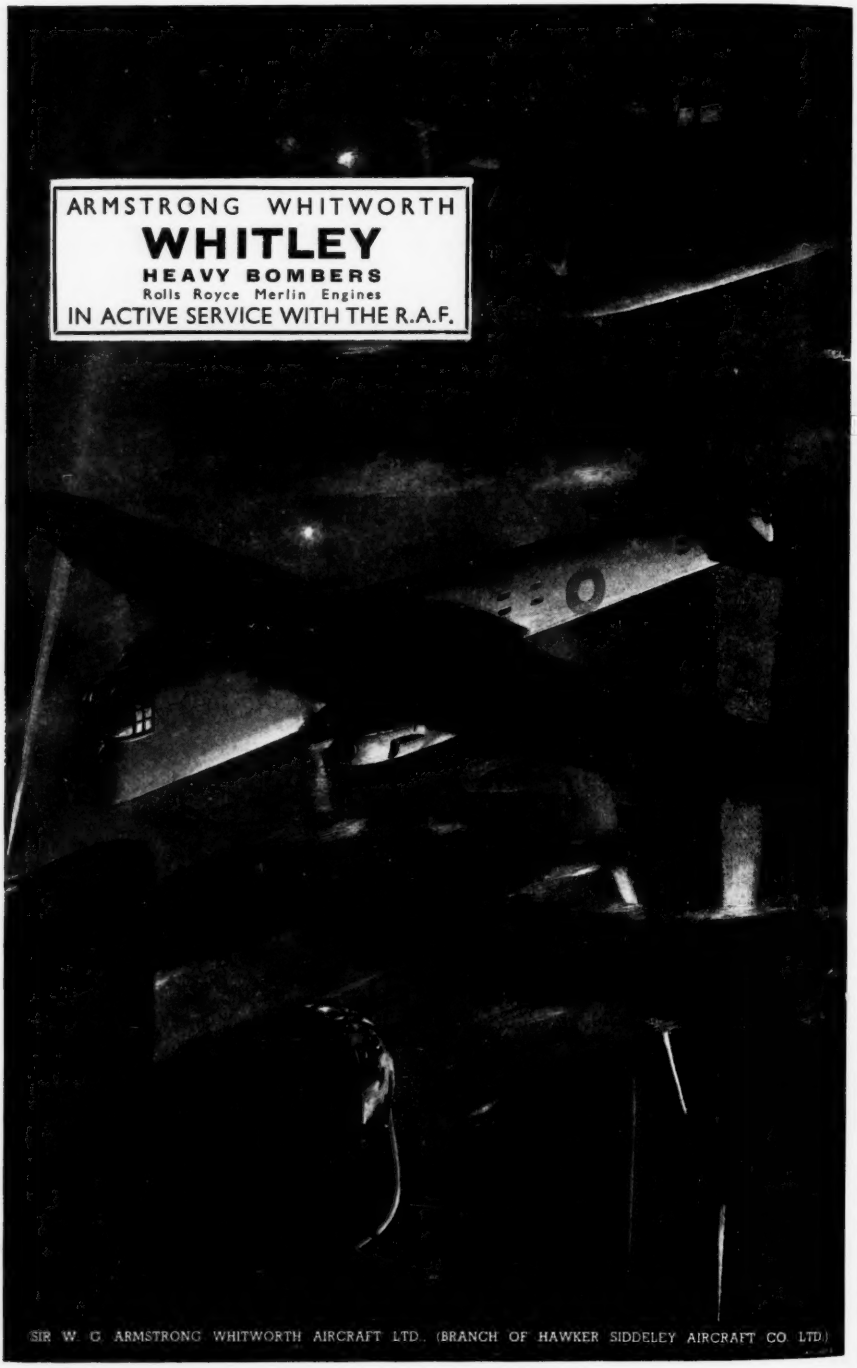
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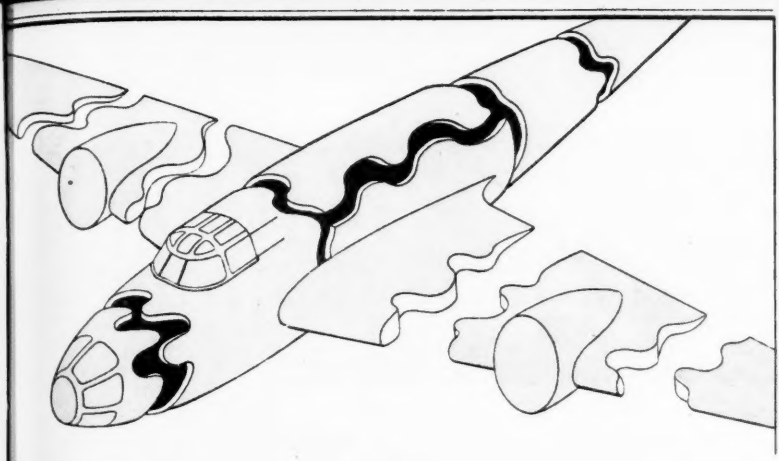

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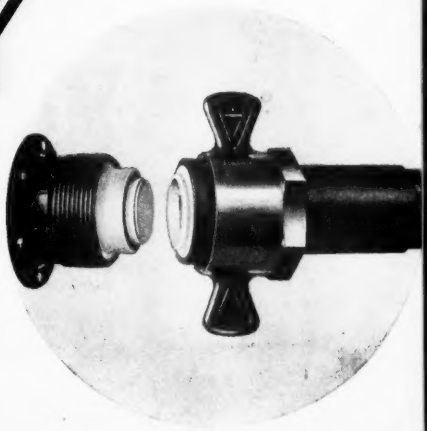

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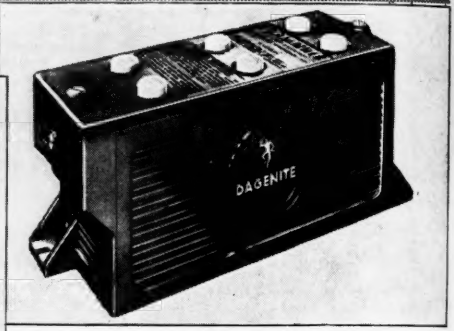

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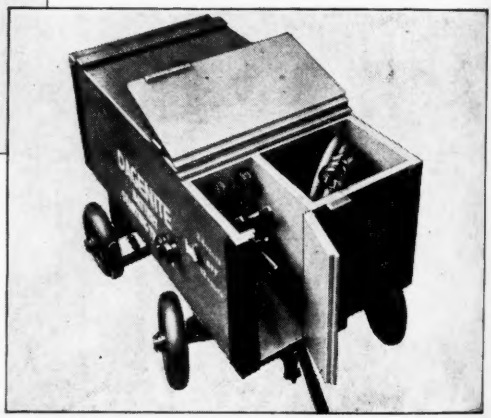

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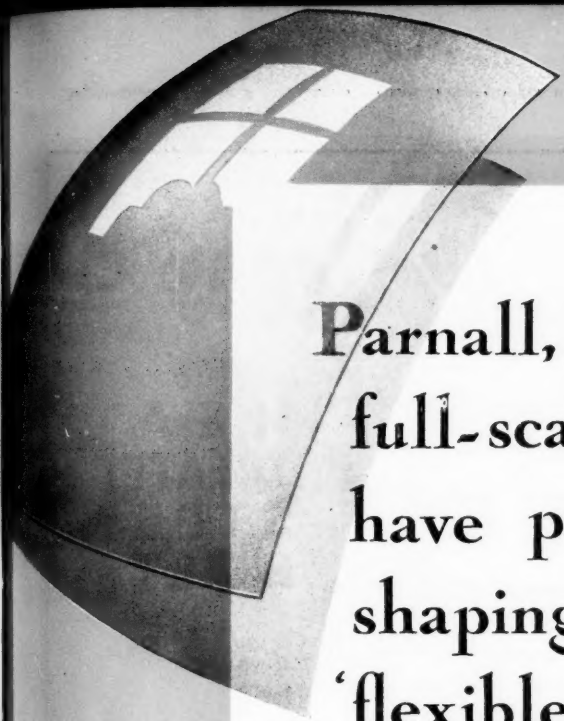

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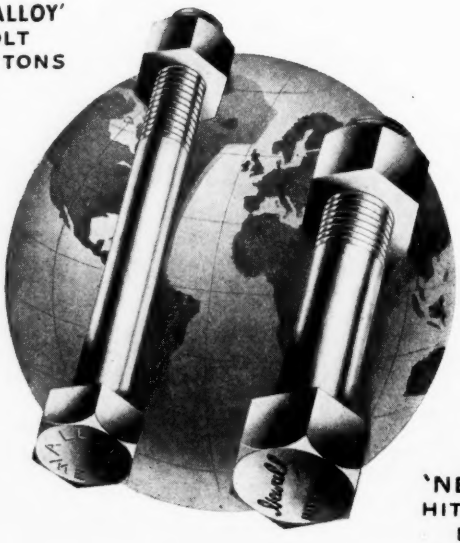

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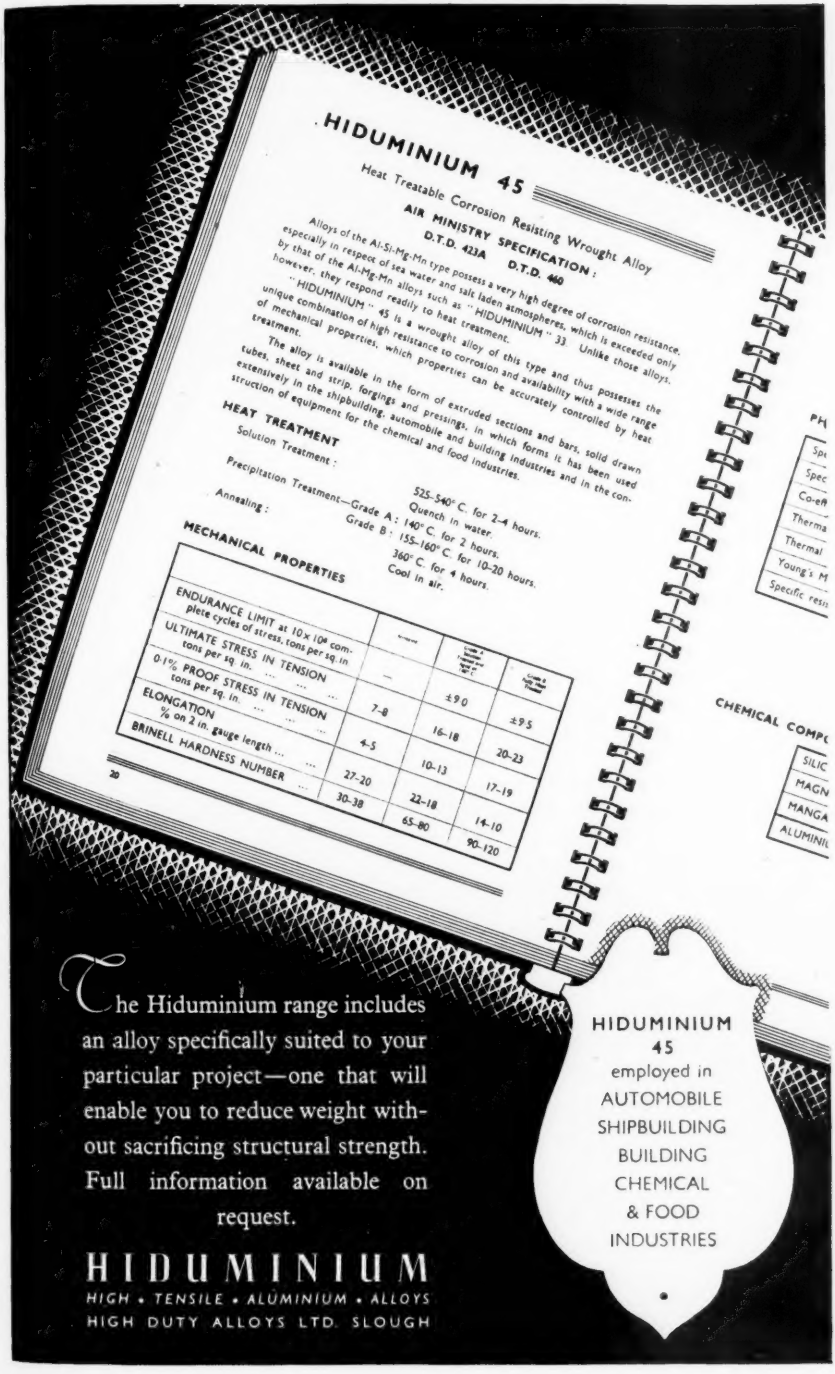
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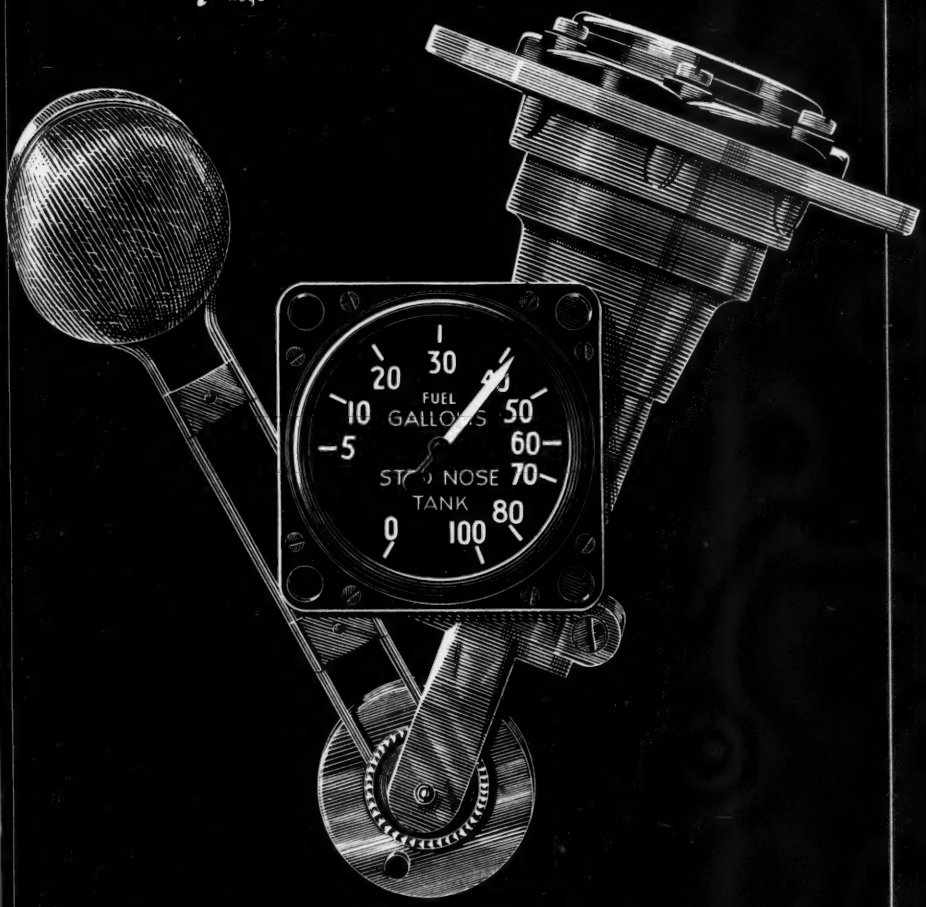

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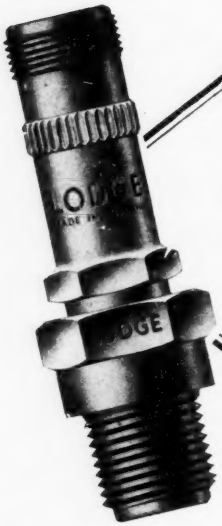

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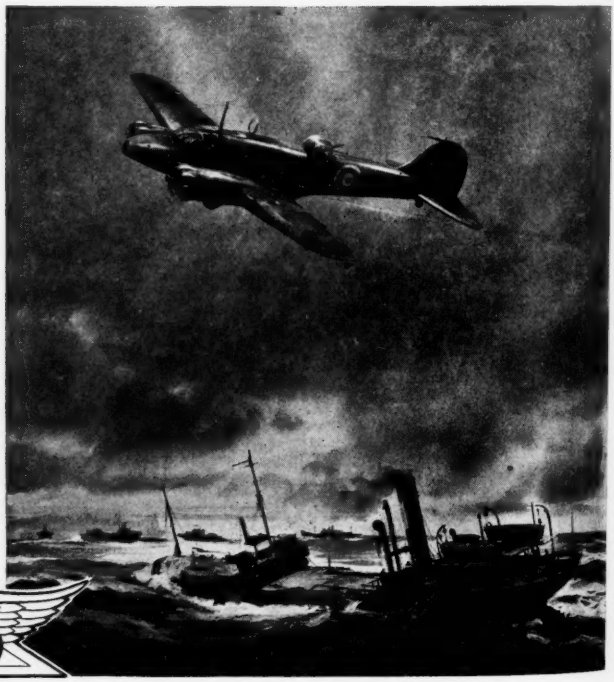

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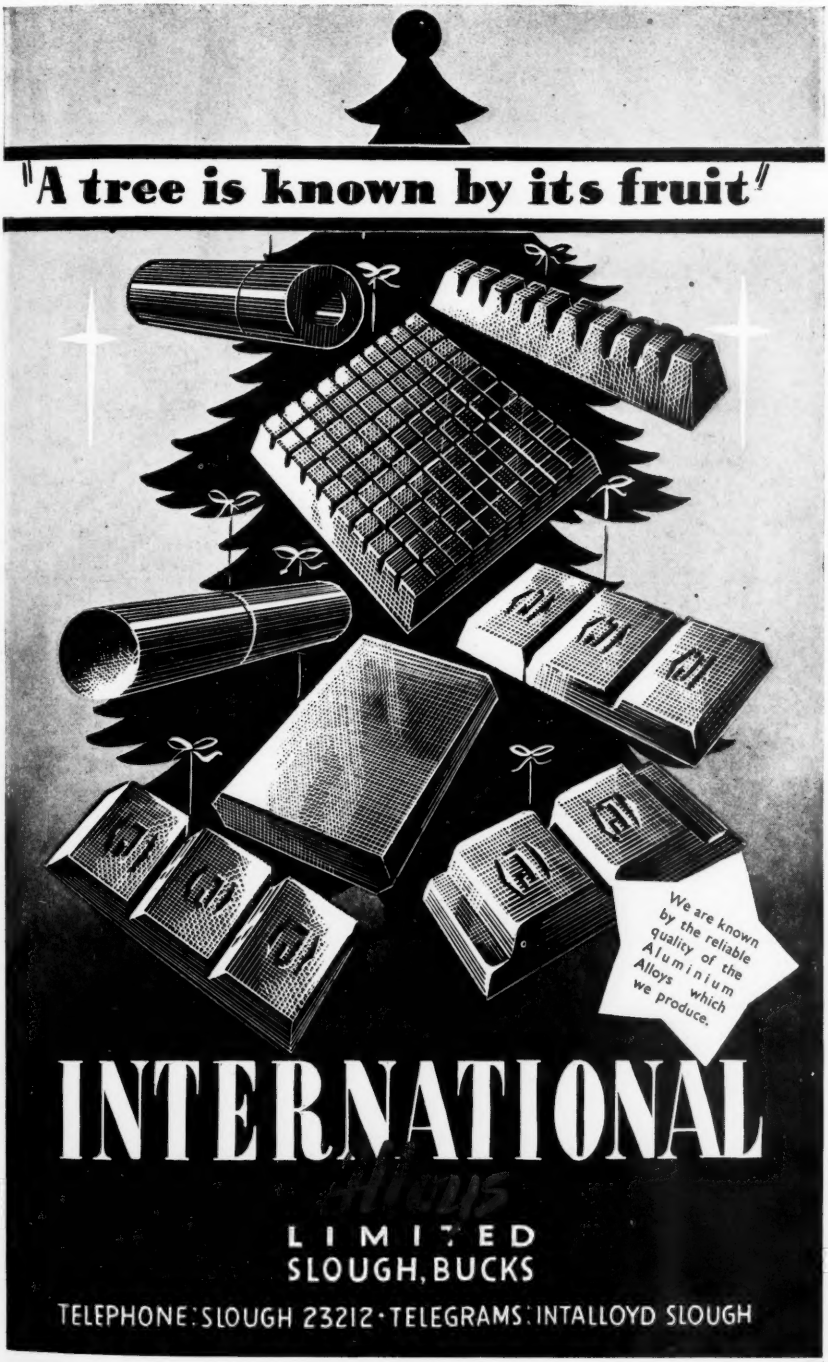
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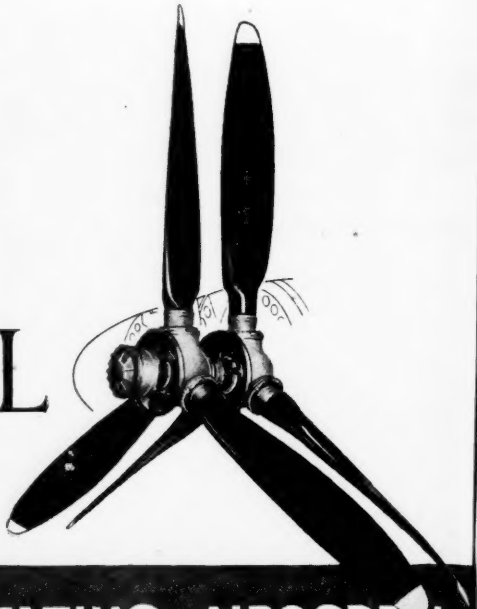

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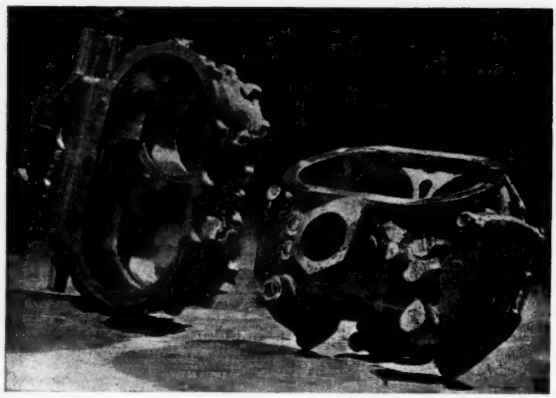

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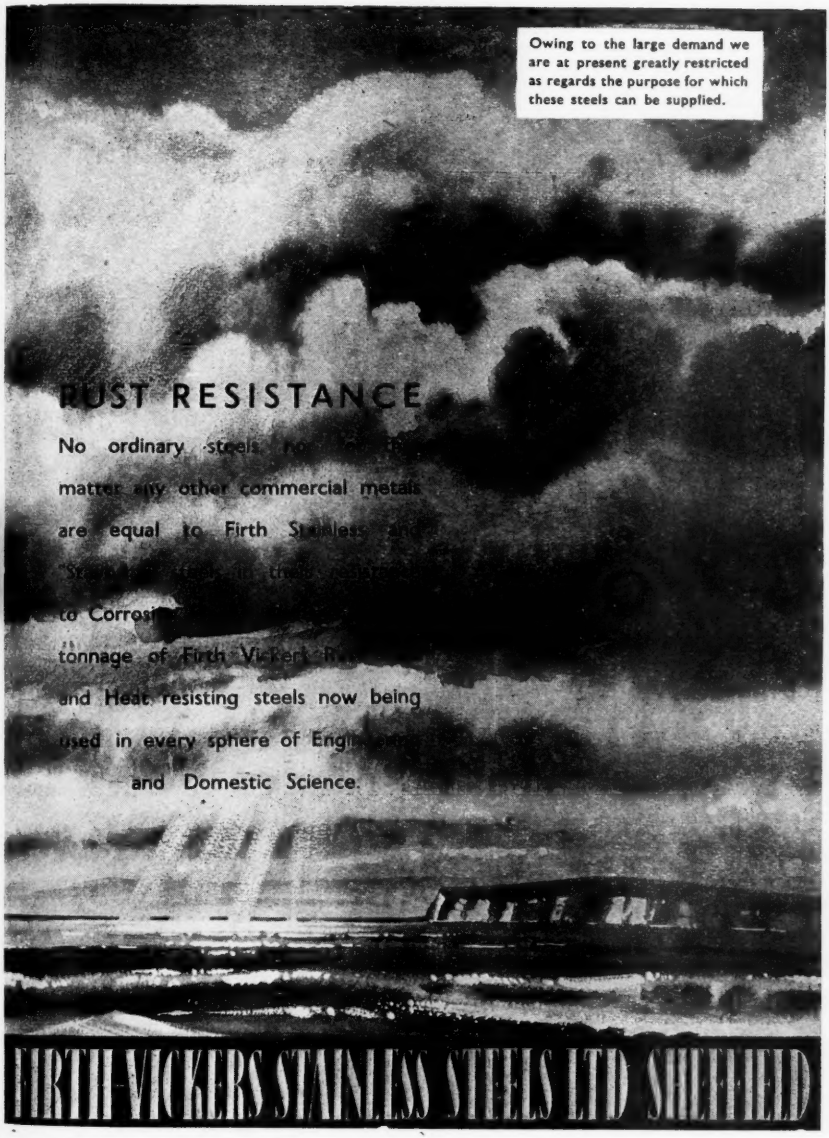
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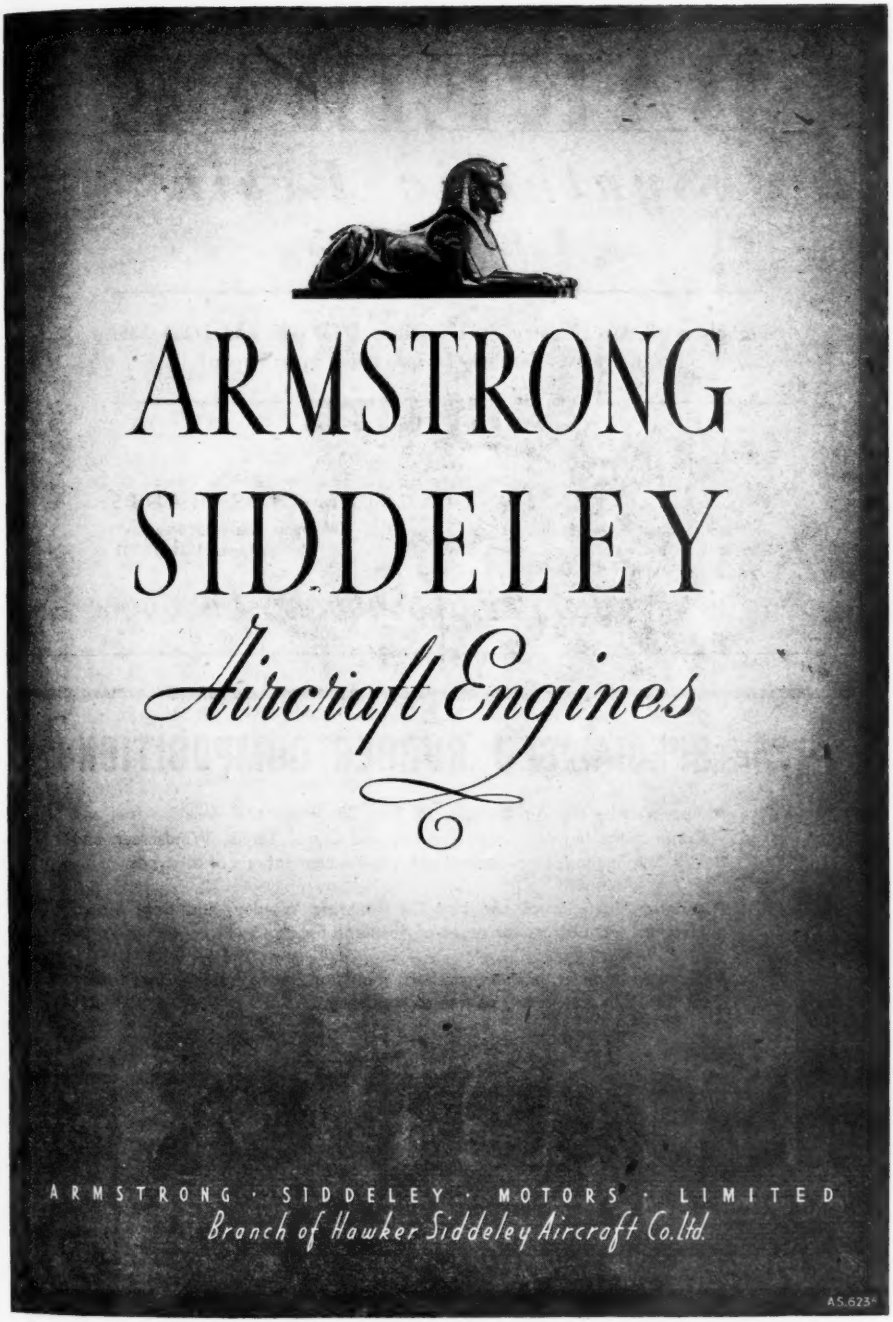
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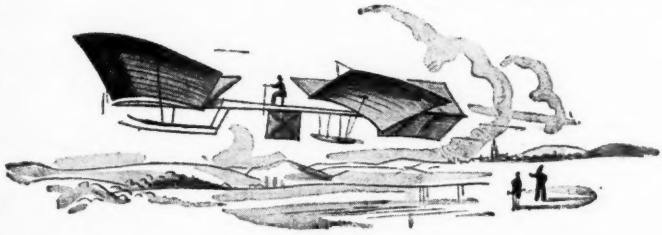

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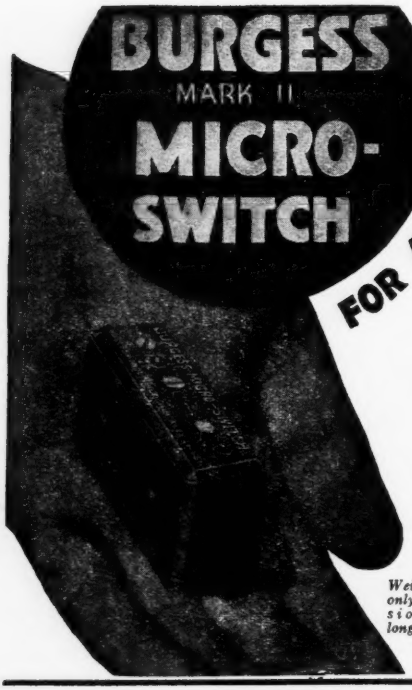

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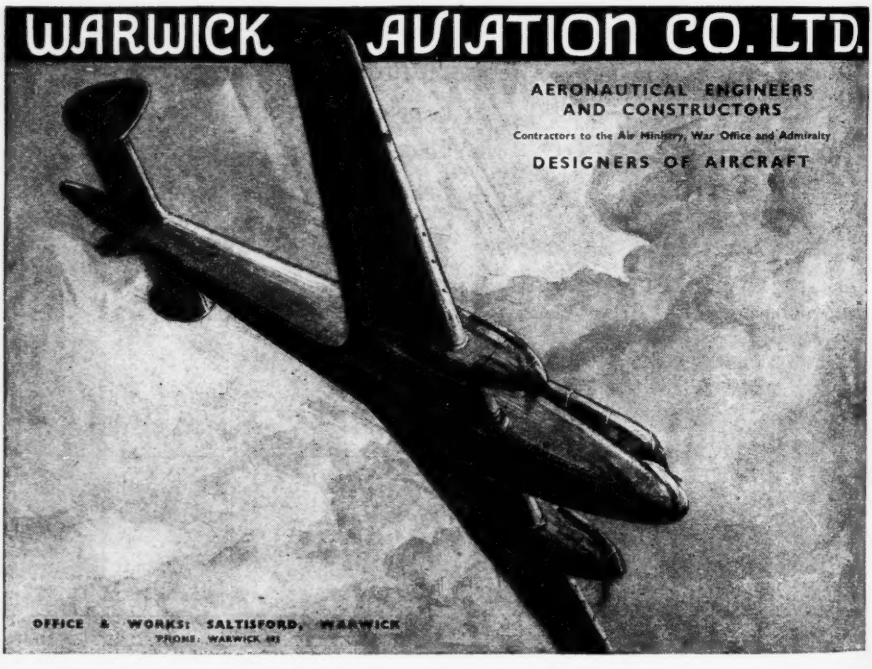
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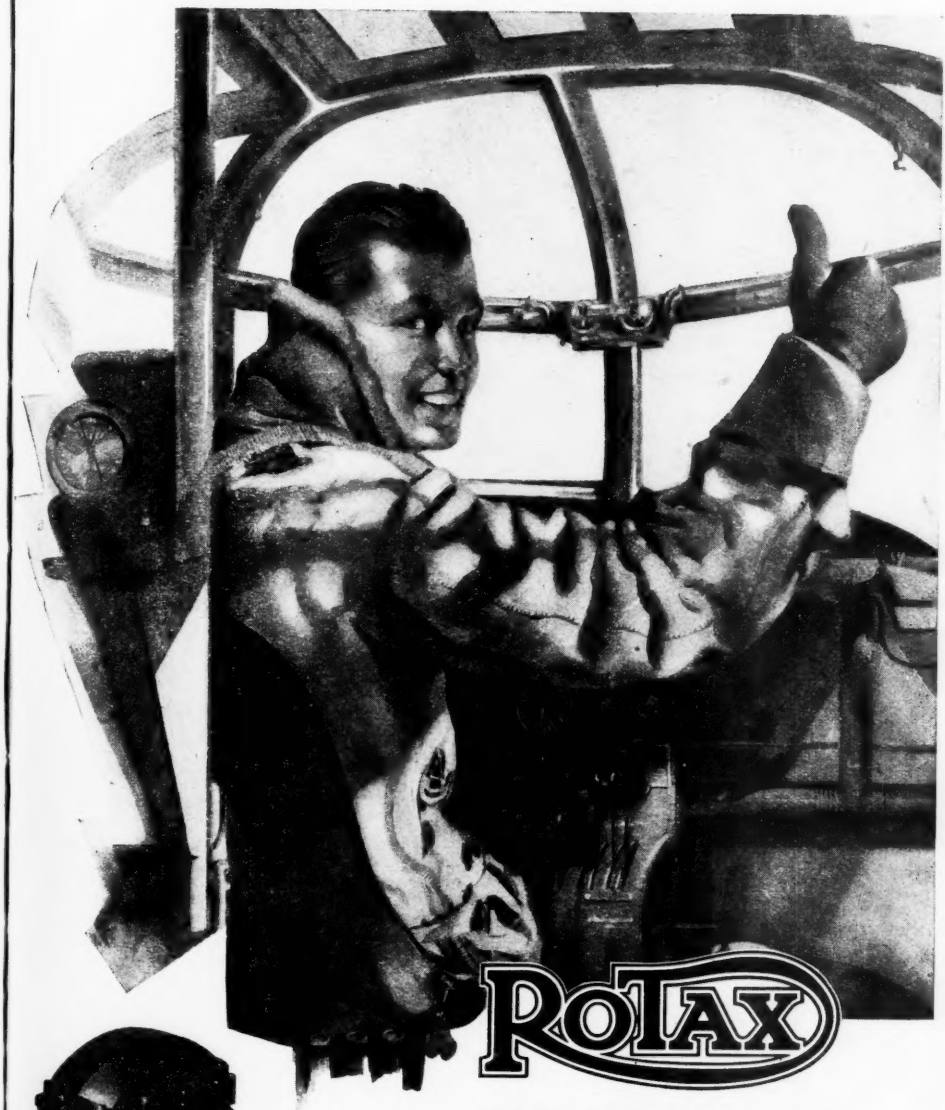

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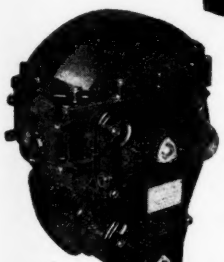

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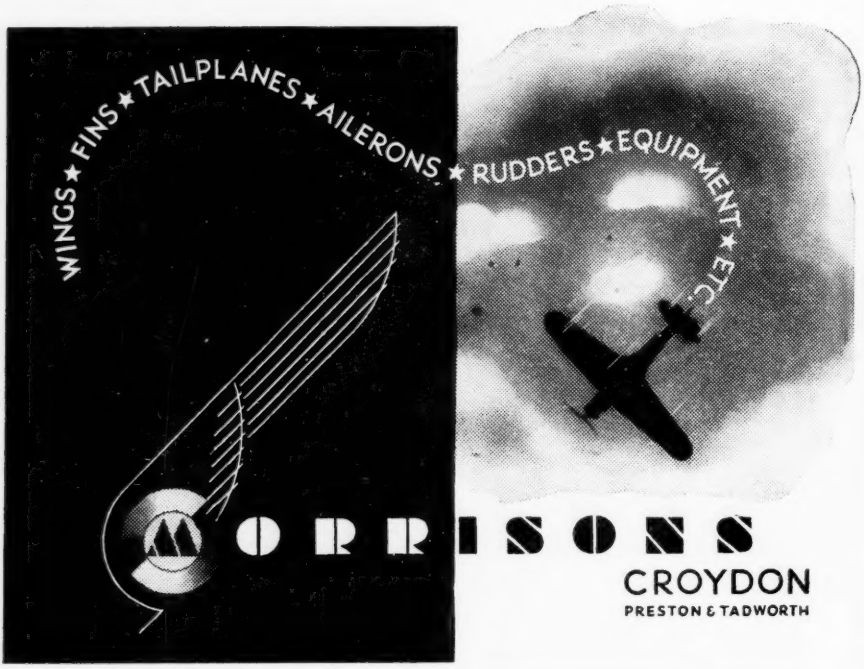

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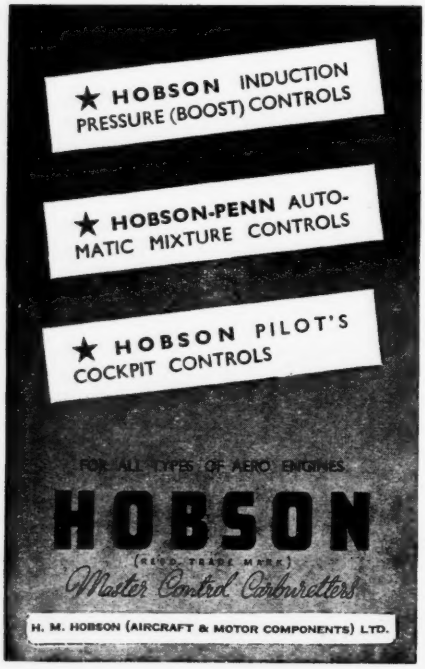
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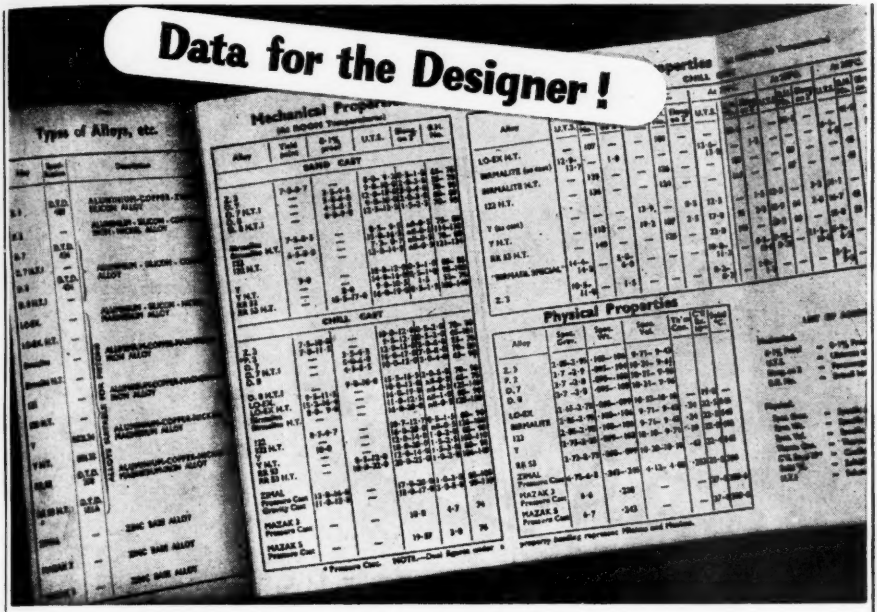

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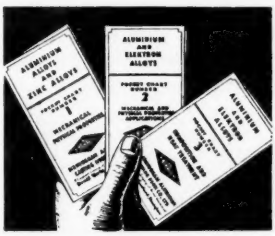

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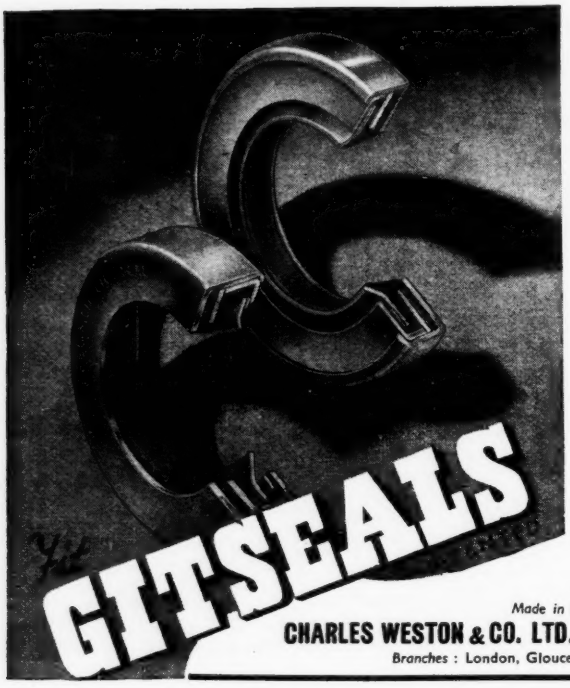

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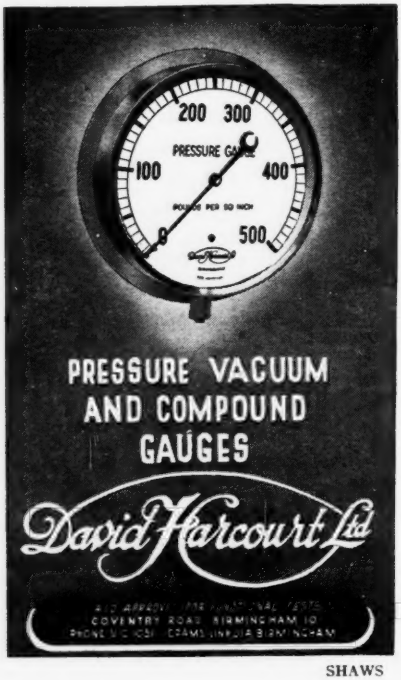

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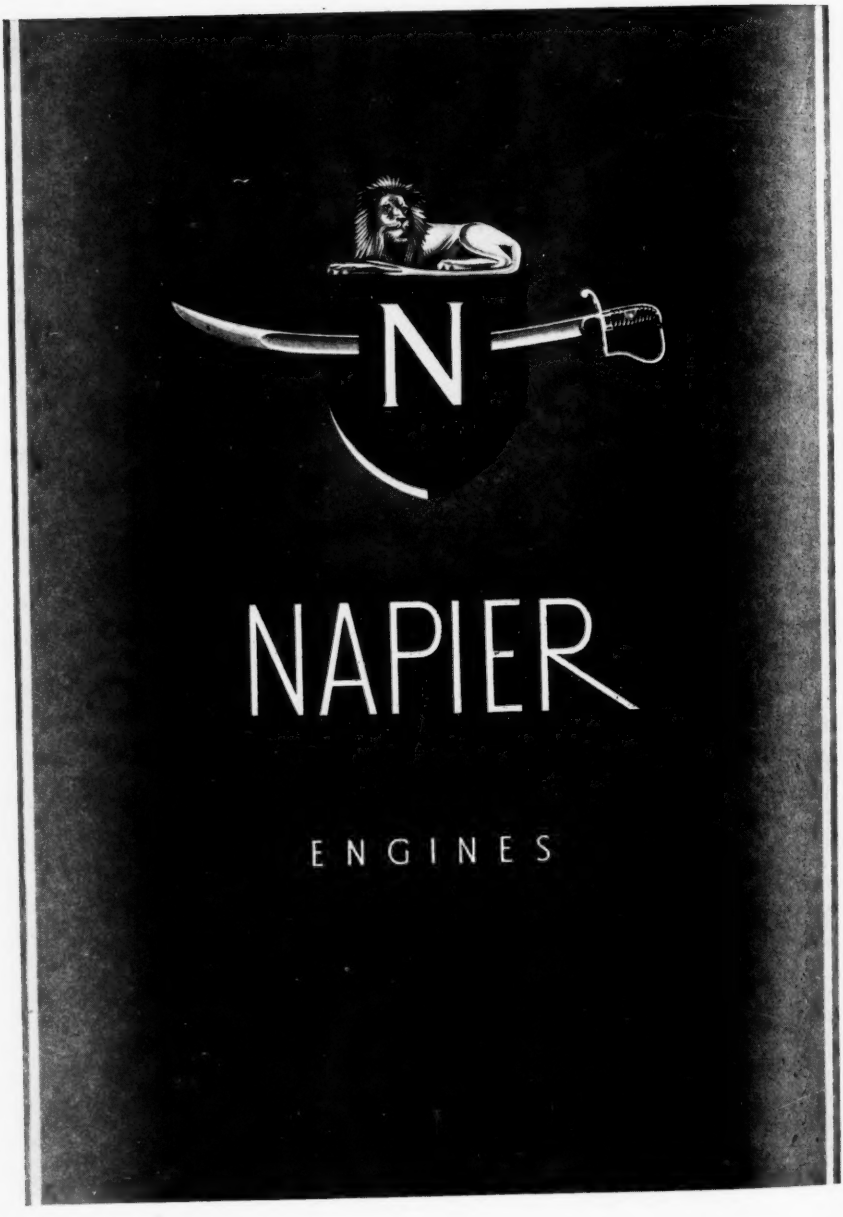
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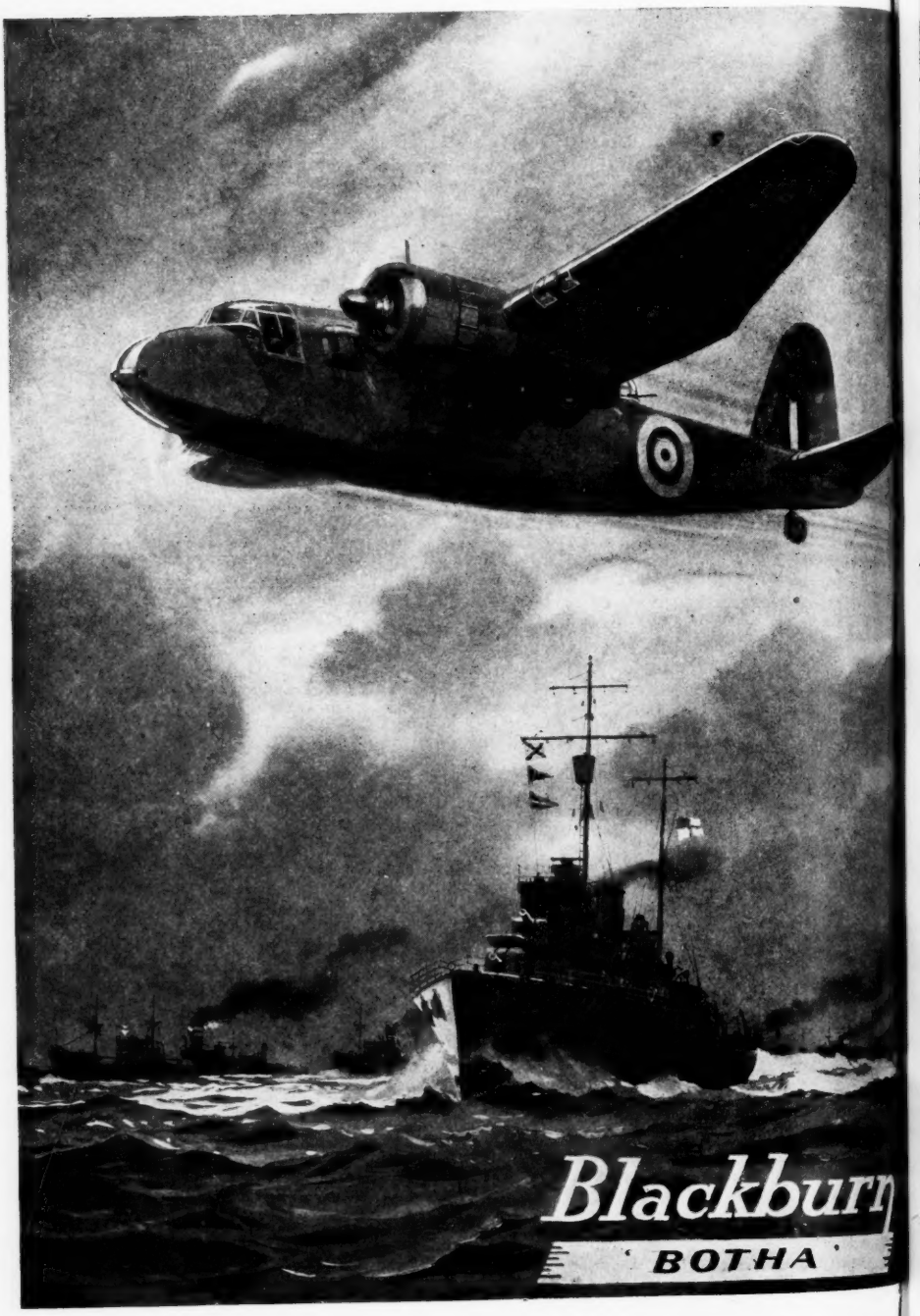
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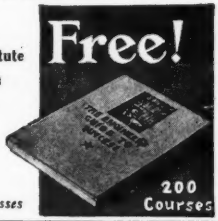

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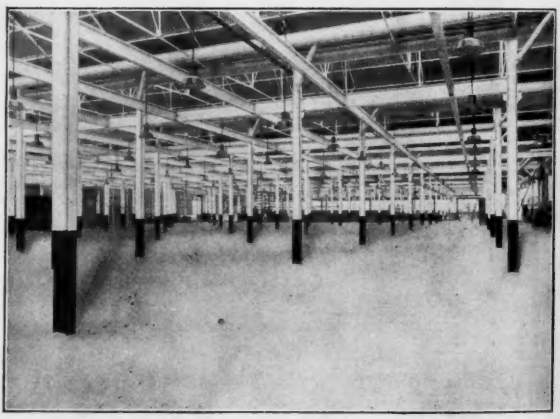

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